Smaller and More Efficient

AC to DC Converter for Laptops

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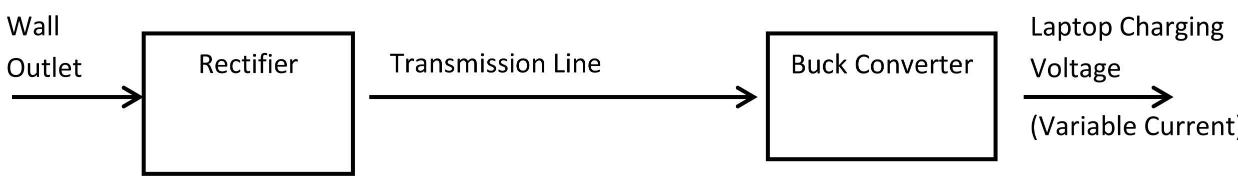
Abstract

The goal of this project is to create a laptop charger that does not have a big box converter. This will be better for the user because the big box converter always gets in the way. This will be accomplished by designing a cable that has several smaller components in it. Figure 1 shows a high level block diagram of how this design could look. The cable must still be able to handle all the power requirements of a laptop charger: to convert high voltage AC to the DC charging voltage. It must also be able to vary the current to depending on the battery level. It must also be as efficient as a standard charger.

Figure 1: Possible Block Diagram for Split Component Converter



I:Problem overview

Problem description

Since laptops are battery powered, they must be charged by a DC current. If they need to be plugged into an AC wall outlet there has to be something to convert AC to DC. The standard laptop charger has a big “brick” converter in the middle of the cord that preforms this function. This brick weighs a lot and tends to be inconvenient to use especially if you have to carry it around. For people who need a lot of computing power (more than a tablet could provide) for extended periods of time they must carry around their big converter. Laptops are getting much smaller but their chargers are not improving at all. This converter could be designed to be smaller, without sacrificing functionality or efficiency.

Market research

This product would be for laptop owners especially those who have older laptops that cannot stay charged as long. Anyone who moves his or her laptop for extended periods of time would benefit from this charger. The laptop market is very large as they are a good combination of computing power and mobility. A Gallup poll found that 64% (±4% at 95%confidance) of people own a laptop. While tablets becoming more popular

they do not have all the features that a laptop has (eg. screen size, processing power, and program selection). Figure 2 shows that tablets are becoming more popular than laptops, but there are still a lot of laptops in the market. They are also portable which makes them more practical compared to desktops if the owner needs to use it in different places. Figure 3 shows that apple laptops have been selling an increasing amount while desktop sales have been declining.

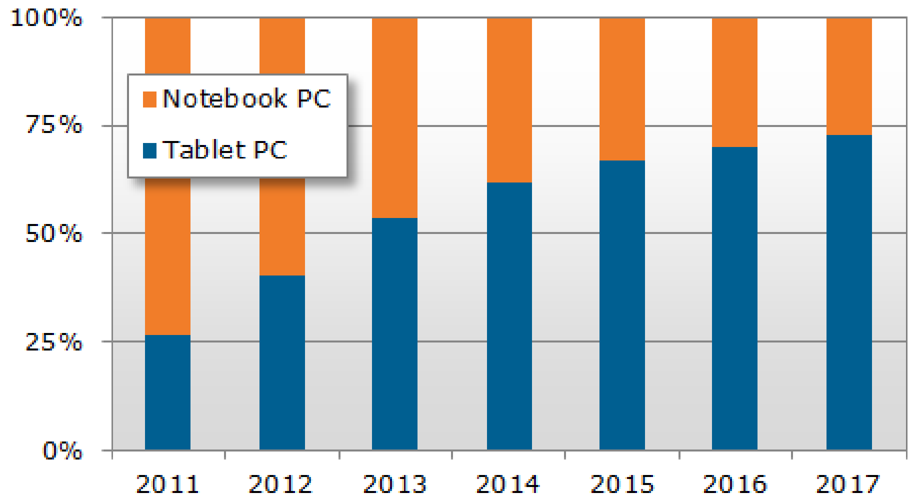


Figure 2: Laptop Vs Tablet Sales (after 2013 is projected)

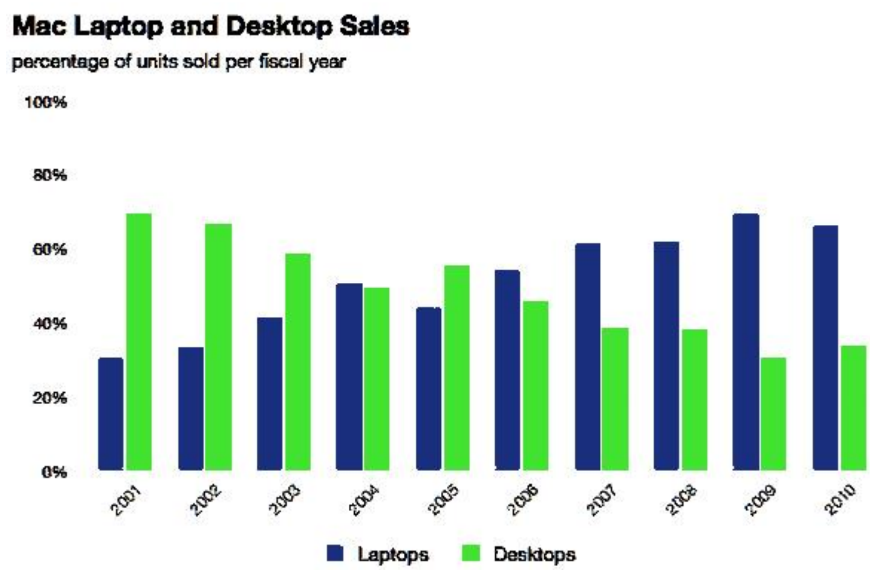


Figure 3: Apple Laptop Vs Desktop Sales

Currently there are a few replacement chargers available. The most advanced is called the dart and is made by a company called FINsix. Their product is set to hit the market November 15, 2014. This product seems awesome but it costs $80 ($150 for mac). Innergie is another company that sells a replacement power converter. This

company's converter is cheaper though the converter (all be it smaller) is still in the middle of the cable. Targus, Duracell, and Dell also have specialized converters, but their converters all have the converter in the middle of the cord and are not that much smaller than the standard charger.

These companies have a very good hold on the market. If I were going to try to make my charger powerful I would attempt to keep costs under $20-15. This would allow me to sell it for $30-25 which would make my product available to the market of people who do not want to spend over $50 but still want a quality charger.

Product Description:

While there are several solutions currently on the market they are all very expensive. I think I can make my design will be cheaper, but still have the same quality. My design will split the converter into several different components attached equally along the cord. This will allow the weight to be evenly distributed throughout the cord. I will also design my converter to be small and very efficient. While I do not think that my design can commercially compete with the available chargers I do think that I will be able to make a small, efficient, and reasonably priced charger.

II:Requirements and specifications

This product is being made as a replacement laptop charger specifically for the HP pavilion laptop, though it can be designed to work for other similar brands and models. The main part of this charger is the AC-DC converter. The main goal of designing this converter is to decrease size of the converter on the cord. This should be accomplished by dividing it into several smaller components dispersed throughout the wire. A secondary goal of this design is that it must be at least as the standard charger. The charger also contains a control input that tells the charger how charged the battery is. This input must be translated to control the amount of current sent to the laptop.

Marketing Requirements (what is needed for my product to succeed in the Market):

- Must cost less than $20 to mass produce
- Must have sleek and polished appearance
- Ideally could have replaceable connectors to charge any laptop

Engineering Requirements (what my prototype will have):

- Must be able to provide 65W (18.5V 3.5A DC) to an HP laptop battery.
- Must be at least 40% efficient (standard charger is 31%), and will hopefully be above 70%.
- Must be as small and lightweight as possible. Ideally lightweight enough that the converter will not have to be resting on the floor for fear of knocking over the laptop.
- Must be built sturdy to withstand being dropped and long term use.
- Must be able to operate from 10°C to 35°C

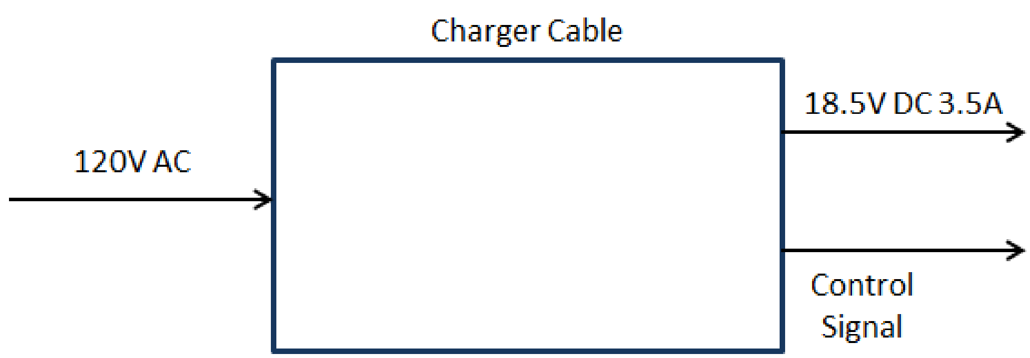


Figure 4: Level 0 Block Diagram

Table 1: List of Input and Outputs

Name	Input/ Output	Description
120V AC 60Hz	Input	Input power from wall outlet
14.5V DC Control signal	Output	DC signal output that is related to the size of charger
20V DC 3.3A (variable)	Output	Charging current for battery, must be able to stop when battery is fully charged

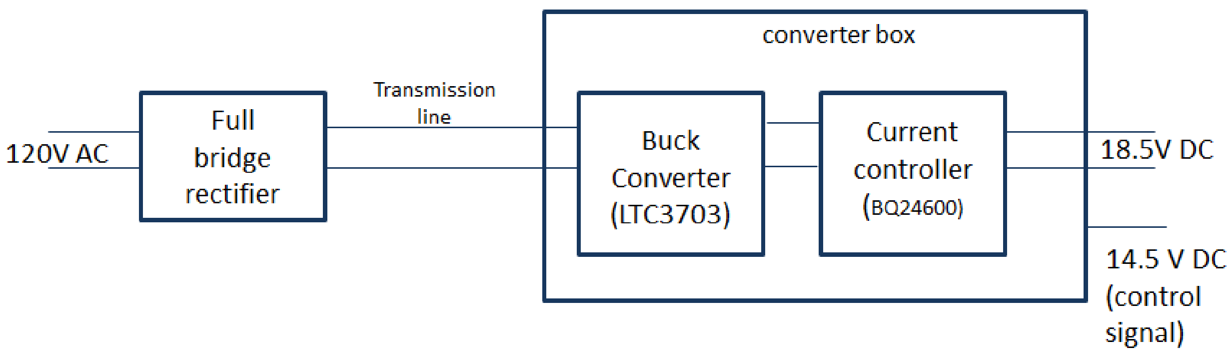


Figure 5: Level 1 Block Diagram

III: Schedule and Miscellaneous Plan

Table 2 shows approximate dates of important project milestones. Figures 6 and 7 show Gant charts for time management winter and spring quarter. These are just tentative and I expect them to change throughout the year. I have tried to include as much time for design evaluation as possible to ensure that my design is the best and not just my first design, these design evaluations will include talking to my advisor.

Table 2: Important Milestones

Date	Event
2-20	Department Wide Review
3-10	EE 461 Demo and Report

5-25	EE 462 Demo and Report
5-29	Senior Project Analysis and Expo

task	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10
charicterize charger charicteristics										
evaluate different high level designs										
design low level circuits										
design physical construction										
evaluate design										
order parts										

Figure 6: Winter Quarter Tentative Gant Chart

task	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10
build and test physical circuits										
troubleshoot design aspects										
begin packaging components										
Test physical components										
finish packaging										
final testing										
finish writing report										

Figure 7: Spring Quarter Tentative Gant Chart

High Risk items:

One of the riskiest parts of this project will be designing the packaging that is small and compact. I do not have as much background knowledge in this area of design. I have left extra time at the end of my schedule just in case this takes longer than expected. Designing the low level circuits could also prove challenging as they will have to mesh with the other components and achieve certain specifications. There is time in my schedule to troubleshoot design flaws.

Table 3: Estimated Costs

item	estimated costs
physical materials	
standard charger	$20
Electrical components	$75
Wires	$10
total	$105

Table 3 offers a very rough estimate of cost. I will not have to pay for labor (myself) or building space (EE building). I will be able to finance this project with the $200 EE senior project fund.

IV: Design

Preliminary design:

The preliminary design (shown in Figure 8 below) that I am considering is to have a rectifier near the wall outlet and a buck converter near the laptop. These components will also be designed as small as possible. This will decrease i^2R losses as well as more evenly balancing components on the cable. I still need to modify this design and consider other high level possibilities. This will take place over winter break and the beginning of Winter quarter 2015. This process will also include a more in depth look at other companies designs.

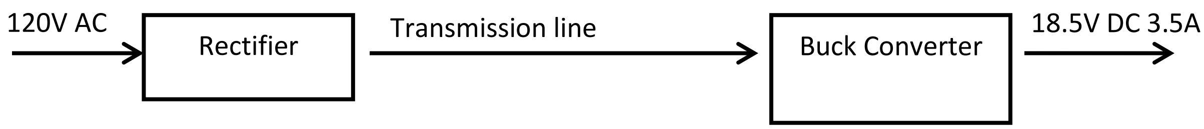


Figure 8: Preliminary Design

Final Design:

For the final design, I chose to use a full bridge rectifier with an output capacitor for because of its small size and simplicity. The high voltage DC output of the rectifier goes into a buck converter, which lowers the voltage to 18.5V. The biggest change to my design was the addition of a current regulator. This is important because without it the battery would draw too much current. I have included descriptions of each of the components that go into greater detail.

Full Bridge rectifier Description:

The first step in converting AC voltage to DC is to use a rectifier to convert the voltage to DC (still higher than the laptops charging voltage). The diodes change the waveform to an absolute value of the sine wave. The output capacitance holds the voltage waveform constant (with some ripple). I chose to use full bridge rectifier because of its small size and simplicity. I used the diodes with the smallest voltage drop I could find to decrease power loss. I also used several smaller ceramic capacitors to decrease equivalent series resistance.

Buck Converter Description:

The buck converter is an efficient way to convert high voltage DC to low voltage DC. I will be using a controller (LTC3703) that will vary the duty cycle of a 500KHz switch in order to regulate the output voltage. This controller uses another MOSFET instead of a standard diode. This will allow me to decrease the voltage more efficiently and with smaller components then a traditional transformer.

Current Controller Description:

The final requirement to charge a lithium ion battery is a component that regulates the amount of current delivered. A simple power supply will deliver too much current too quickly and harm the battery. Texas Instruments makes a controller (BQ24600) that limits the current and safely regulates the battery. This chip is specifically designed for charging a six cell lithium ion battery, which is what a laptop runs on. It operates in three states: a pre-charge (low current), a constant current phase, and finally a constant voltage phase. This allows the battery to store the most energy.

V: Construction

To construct the full bridge rectifier I soldered the diodes and capacitors into a section of the wire (see figure 9). This made the design less bulky than a prototype board would have. I was very careful that the wires did not touch each other. Once it is tested I will use insulating tape to prevent any short circuits or accidental electrocutions.

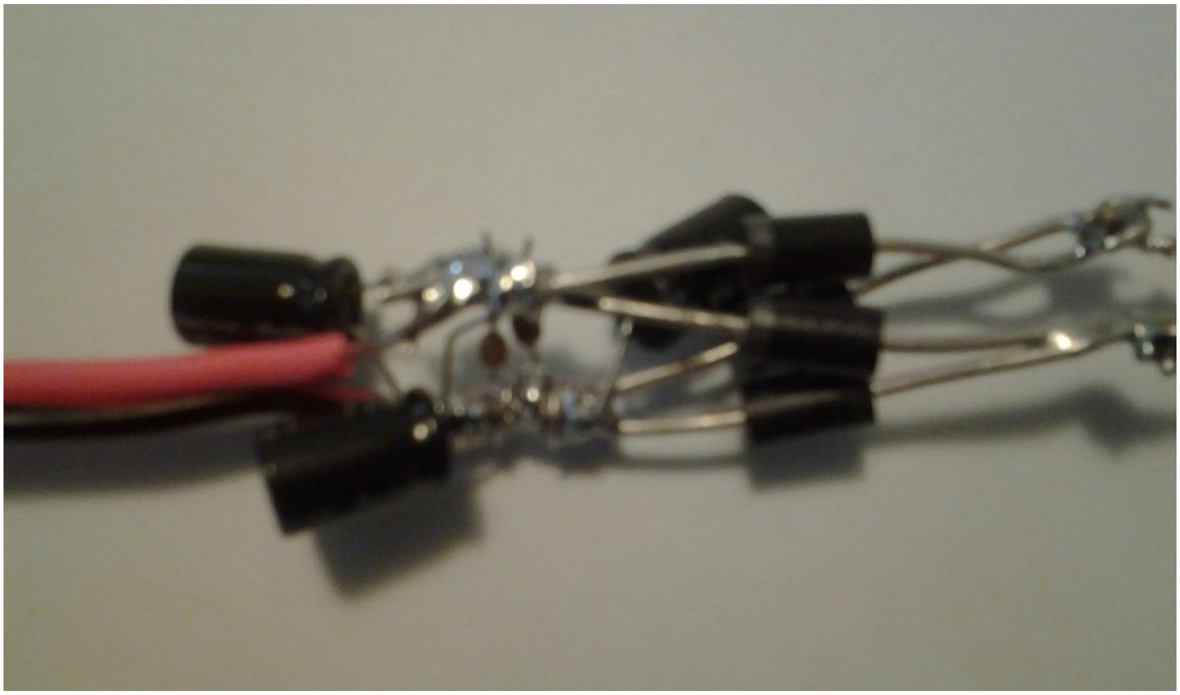


Figure 9: Full bridge rectifier circuit construction

The buck circuit and the current controller were constructed by soldering electrical components to prototype boards that have holes and metal pads for through hole soldering (see figures 10 and 11). Pins were connected to components via solder bridges. Jaime Carmo soldered the surface mount components to through hole adapters.

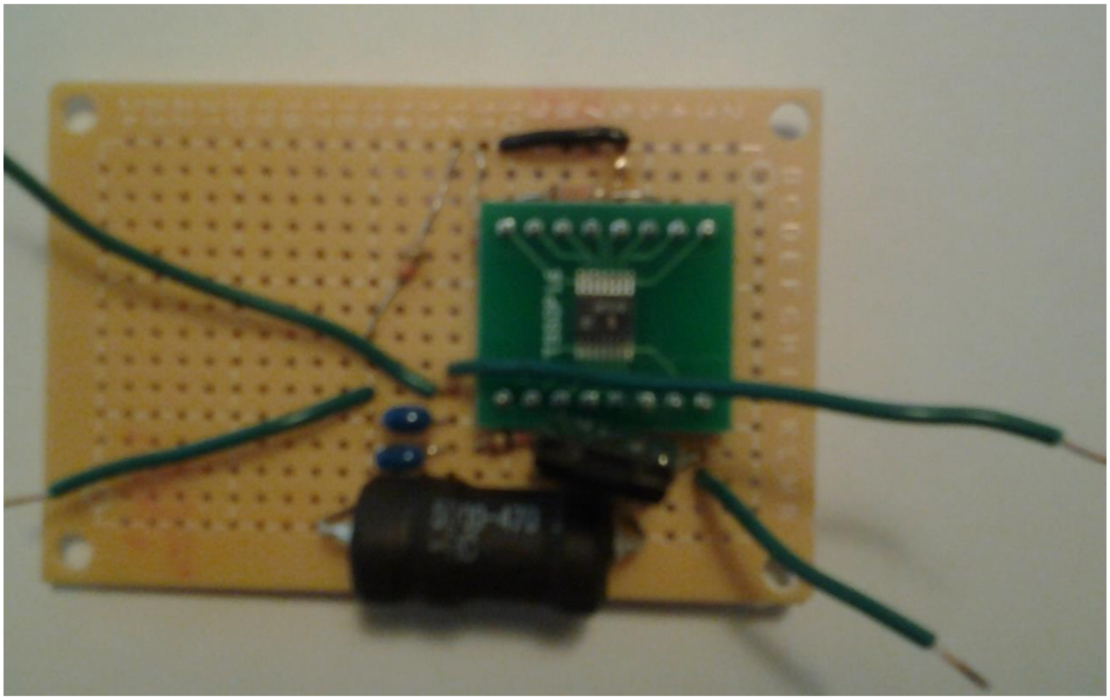


Figure 10: Buck Circuit

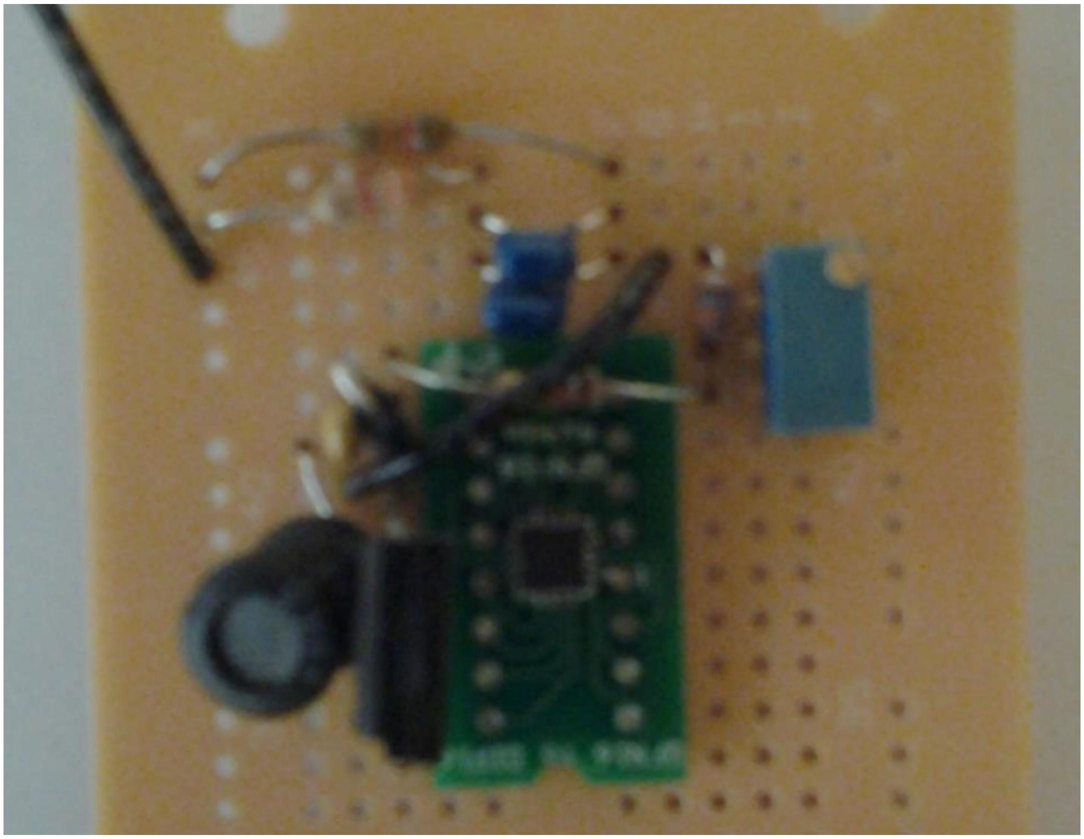


Figure 11: Current Controller

VI: Testing procedure

The following outline explains the testing procedure for each of the components. They will be tested separately to ensure that they work before connecting them. The charger will also need to be tested over long periods of time to ensure that it is reliable.

- Rectifier test
  - slowly increase input voltage from 20V to 120V while monitoring output voltage to ensure that it is connected right and components are not overheating
  - Also test with a .5A load current
- buck converter
  - test with 120V DC input from source
  - measure output voltage while varying the load from 0 to 3.5A
  - re-measure output voltage using output voltage from the rectifier to power buck converter
- Complete product
  - Simulate battery voltage level and observe the output current
  - connect full product to laptop while monitoring output pins from current controller to ensure it is charging correctly

VII: Test Results

The rectifier did not work as desired. It worked for the no load test, but adding any load would introduce a massive voltage ripple (figure 12). I used a 300Ω resistive load to draw .5A. This is because the capacitors are too small. By adding more capacitors in parallel, I was able to decrease the ripple but it was still significant. The solution is simply to add bigger capacitors. Because none were available I used the bench capacitor to add more capacitance which game me a more ideal output (figure 13).

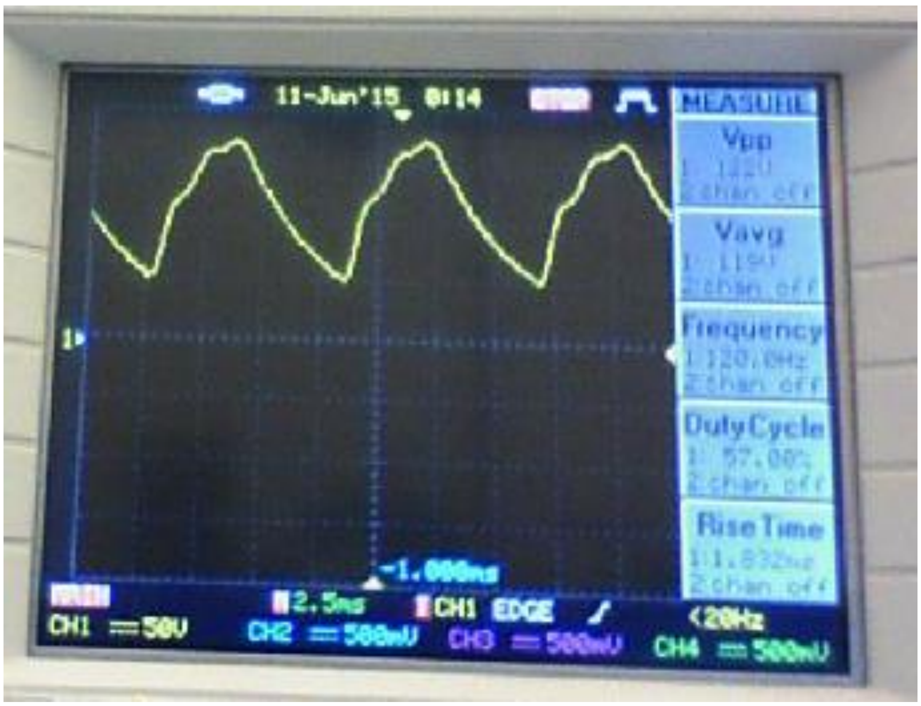


Figure 12: Rectifier Output (50v/div Vavg=120v vpp=120V)

Figure 13: Rectifier Output with added 7.4mF capacitor (Vavg=158V Vpp=6V)

The buck circuit failed the tests. When hooked up to high voltage the output would follow the input (suggesting the MOSFET may not have been switching correctly). Both the MOSFET and the IC burnt out. After rechecking the circuit I tried it with a new IC and MOSFET but it did not function and subsequently burnt out. Since I only had two controllers, this meant the end of the troubleshooting process.

Possible Fix:

To get the rectifier working well, bigger capacitors need to be added to the output. The buck circuit must be redesigned. I suspect that several voltage ratings (specifically the MOSFET's but also possibly the controller) were too low. Also if I were redesigning the board I would place the components farther apart. While this would increase the size (which I was trying to limit) it would help with heat dissipation and make trouble shooting and replacing broken parts much easier.

IX: Conclusion

The goal of this project was to create a smaller and more efficient laptop charger. The way I chose to design it was to have three separate components spaced throughout the wire. These components would be less annoying and bulky than the single brick converter that is the common design. I chose to use a buck converter, instead of a transformer, to lower the voltage because it is smaller and more efficient.

Unfortunately the charger did not work. The Capacitors at the output of the full bridge rectifier were not large enough to keep the voltage constant. More critically, some unknown aspect of the buck converter was not designed with high enough power rating and both controllers burnt up.

This project was challenging because efficiency was often proportional to size. Many components that are more complex might have been more efficient but would also use more space. To decreasing size, a compact layout was also needed. This made it difficult to effectively troubleshoot and replace broken components. It also hurt the heat dissipation of the component.

This project presented challenges in designing a system that was more efficient than the current charger and more convenient to use. While it did not work, dividing the charger into three components is a viable option that would make the charger smaller.

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