Eric Weiler - Rho Psi Society 2014 Science and Technology Scholarship Project Report Submission

Written Project Report

"Custom-Made External Battery Charger for Smartphones and Tablets"

Research and Design

I began my research by looking at my smartphone itself. I own a Google Nexus 5, a very typical Android phone powered by a Micro-USB to USB cable (figure 1) just like every other Android phone. The Micro-USB-end is plugged into my phone and the USB-end is plugged into any USB power source such as a wall charger or a computer. I wanted my charger to be *universal*; I wanted it to be able to charge Android phones *and* iPhones. All Apple devices use a different cable designed by Apple and come in two different formats shown below. Figure 2 shows the old pre-2012 Apple connector and Figure 3 shows the new post-2012 *lightning* connector.

Figure 1

Figure 2

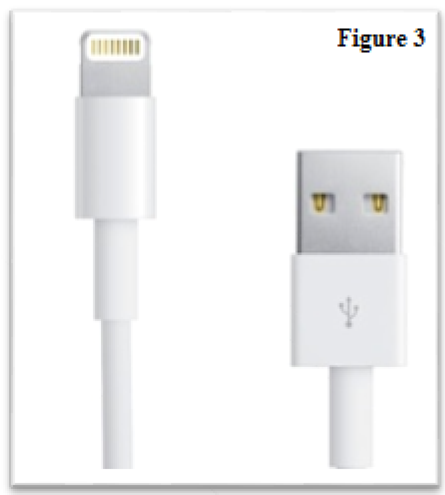


Figure 3

All of these cables have one thing in common: a USB connector. It doesn't matter what kind of device you own, ultimately you are getting your power via a USB connection. From this information I incorporated a simple USB port output on the design of the charger so that way any phone can be charged from it.

One of the defining characteristics in the designing of my charger was based on the electrical characteristics of a USB, the fact that all USB devices are powered by 5 volts of direct current (DC). My Nexus

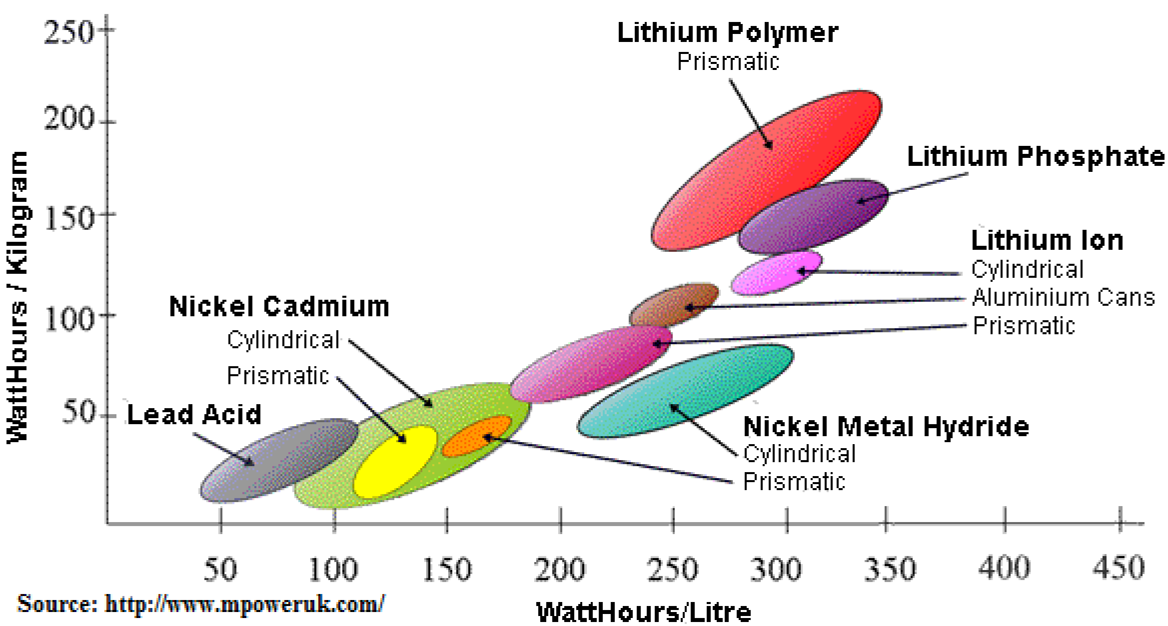
5, like nearly every other smartphone nowadays including iPhones, can be charged with 5 volts at a rate of up to 1 amp, or 5 watts. A traditional USB port found on a laptop or a computer is able to output 5 volts of current at 0.5 amps, or 2.5 watts. Most wall chargers provided with smartphones are able to charge at rates of at least 1 amp, the wall charger provided with my phone is capable of charging it a rate of up to 1.2 amps (shown on the left). The higher the current rating of the power source the faster a phone's battery can be charged, however, if the current is too high there is a risk of damaging the battery. Ideally, with this in mind, I wanted my charger to be able to output at least 1 amp of 5 volt power. Now came the challenge of producing 5 volts of power through using a battery.

One of the most important factors in deciding what battery to use would be the nominal cell voltage. As it turns out, there is no common battery that has a nominal cell voltage of exactly 5 volts, most batteries have voltages under 5 volts with the highest nominal cell voltage belonging to lithium-based cells at 3.7 volts per cell. In order to increase voltage, multiple cells can be wired together in *series* so that the voltage is multiplied. For example, two 1.5 volt alkaline batteries can be wired together in series to form a "battery pack" that produces 3 volts. Unfortunately, no matter how you wire the batteries, no matter which battery type you choose, it is impossible to create a battery pack with exactly 5 volts. Even if there was a perfect battery with a voltage of 5 volts, due to the nature of batteries, the voltage would drop over time as the battery discharged and the power would not be usable; the power that was required had to be *regulated*.

I decided to use a *voltage converter* to achieve the desired 5 volts of regulated power. Voltage converters come in step-up and step-down variants. Step-up converters are used to increase voltage and step down converters are used to decrease voltage. For example, a 12 volt step up converter will convert voltages below 12 volts to 12 volts and a step down converter will convert voltages above 12 volts to 12 volts. Voltage converters also have the ability to produce regulated power, regardless of the dropping voltage of a battery as it is being used.

Next came the task of choosing the right battery. Below is a table of six of the most common types of batteries and their specification followed by a chart of battery energy densities.

Type of Battery	Alkaline (reference)	Lithium-Ion (Li-Ion)	Lithium-Polymer (LiPo)	Nickel-Metal Hydride (NiMH)	Nickel-Cadmium (NiCd)	Lead Acid
Image						
Nominal Cell Voltage	1.5 volts	3.7 volts	3.7 volts	1.2 volts (The above image has 3 cells so it would be 3.6v)	1.2 volts	2 volts (usually with six cells in series to create 12 volts)
Number of times cell can be recharged	Non-Rechargeable	700	1000	500-1000	500	500-800
Cost	$	$$$	$$$$	$$	$$	$$



I decided to go with a single Lithium-Ion Cell because a single cell had a relatively high nominal cell voltage of 3.7 volts meaning that I could just use one cell by itself and connect a 5 volt step up converter. Regular common alkaline batteries that you can buy at the grocery store was not an option because it is not rechargeable and would not be cost effective over time. Lead acid batteries like the ones that are used to start cars was also not a viable option because even the smallest lead acid batteries weigh 1-2 pounds. Nickel-Metal Hydride and Nickel-Cadmium batteries were a good choice but a nominal cell voltage of 1.2 volts for each cell was too low, I would have to wire three or four in series in order to get near 5 volts (3.6 and 4.8 respectively) and that would be too much of an inconvenience. Lithium-polymer cells were a very close candidate for the cell I wanted to use because it too had a nominal cell voltage of 3.7 volts. The only downsides to Lithium-polymer cells were that they were slightly more expensive, more dangerous to charge, and slightly less energy dense than Lithium-ion cells.

Information about my choice of Lithium-Ion Cells:

- Lithium-Ion cells have a nominal cell voltage of 3.7 volts, think of nominal as “average”. When Lithium-Ion cells are fully charged they have a voltage of 4.2 volts per cell and when they are fully discharged they have around 3.2 volts per cell.

So far I already had two items on my list for things that I needed to buy for my charger: (1) the battery, and (2) the 5 volt step up converter. Because I was going to be using rechargeable lithium-ion batteries I had to add one more core component to my list: a compact lithium-ion battery charger module. This module would be built into the charger itself so that the whole unit would be contained within itself and would not need me to remove the lithium-ion batteries to charge them using an external charger. After browsing online I found all of the parts I needed. I added a few other small materials to the list of things that I needed to buy and came up with a final materials list:

1. Two Panasonic 3.7v 3400 mAh 18650 Lithium-Ion Batteries

2 PANASONIC NCR18650B LI-ION BATTERY 3400mAh 3.7v 18650 N... (370925377492)

r-lsales | 146311 | 99.7%

Sale date: 03/17/14
Tracking number: 9400109699938298060000
Delivered: Sat. Mar. 22

$19.85
Free shipping

- I decided to buy two batteries so that I could wire them in *parallel* so that the capacity of the batteries would double to become 6800 mAh. 18650 refers to the size of the cell: 18mm diameter, 65mm high and a "0" at the end indicates that the battery is a round type. I could have gone with a larger 28650 battery that already has a larger capacity to avoid having to wire these two in parallel but then the whole unit would be built around this large and awkward round cell.

2. Two 3V to 5V 1 Amp USB step up converters

DC-DC Converter Step Up Boost Module for MP3 MP4 Phone 3V... (360822305402) $6.82
Quantity: 2
Sale date: 03/17/14
Tracking number: 9274899999933011656359
Delivered: Tue. Mar. 25

- I planned on buying a step up converter with standard positive (+) and negative (-) inputs and outputs. I would have wired the batteries to the input and a USB port to the output, however, I found the perfect step up converter that already had a USB port built in to the output. Step up converters have a limit to how low the input voltage can be, the lower the input voltage the "harder" the converter has to work to convert it to a higher voltage; *the lower the input voltage the lower the efficiency*. This one has a lowest input voltage of 3.0 volts, this was perfect because as stated earlier, Lithium-ion cells have a working voltage that ranges from 3.2 to 4.2 volts. This step up converter also has a maximum current output of 1 amp with was right where I had set my goal. I decided two buy two so that the charger would be able to charge two devices at once just like how most consumer-grade chargers work. These two chargers would be wired in parallel with the battery to draw the same current.

3. Mini Lithium Battery charger – powered by 5 volt mini USB input.

Mini USB 5V Lithium Battery Charger Board 1A Module /w Le... (161222179541)

victoryrush | 3692 | 99.9%

Sale date: 03/17/14
Tracking number: 9400109699939752503859
Delivered: Thu. Mar. 20

$5.59
Free shipping

- The outputs of this Lithium Battery charger would be wired to the positive (+) and negative (-) terminals of the battery and would be able to charge them by connecting a USB cable, just like how consumer-grade external battery chargers work.

4. Mini LED voltmeter

DC 0-32V LED Panel Mini Voltage Meter 3-Digital LED Displ... (360863044951)
Color: Blue
Sale date: 03/17/14
Tracking number: 9274899999933011656359
Delivered: Tue. Mar. 25

$3.79

- The final core component I decided to add was a voltmeter so that I could track the voltage of the batteries as their energy was used up and essentially know when my battery charger was getting “low”. This voltmeter also will be wired in parallel with the rest of the core components and to the battery. A voltmeter is necessary because Lithium-Ion cells can be damaged if their voltage drops below 3.0 volts.

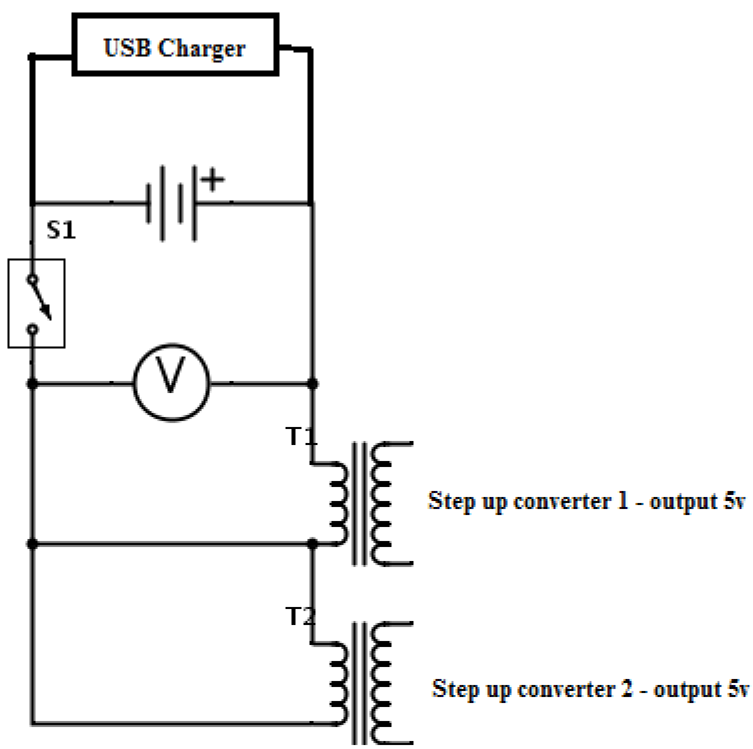
5. Slide switch – $0

   - Used to turn device on and off, I already had one at home they can usually be found at radio shack for a couple cents.

6. Wire - $0
7. Solder - $0
8. Glue - $0

Total Cost (all items came with free shipping) = 3.79 + 5.59 + 6.82 + 19.85 = $36.05

Design Schematic



Finished Product