Boosty-bit:

Power for Pint-Sized Projects

Timothy Grijalva

Winter Quarter 2014

Advisor: Dr. Bridget Benson

Table of Contents

List of Tables

List of Figures

Abstract

In order to make it easier for hobbyists to create small portable microcontroller based electronics projects, I have created Boosty-bit, a tiny DC-DC boost convert that runs off a single alkaline battery cell (AA or AAA). The Boosty-bit converter can source up to 250mA @ 3.3v, making it ideal for many microcontroller based projects. In addition to power management, Boosty-bit is also physically small, allowing it to fit inside pen/marker-sized enclosures along with a AAA battery and a microcontroller. Boosty-bit aims to be the ideal solution for "makers" who desire portability and compact form factors in their projects.

Introduction and Background

"Maker" is a relatively new term used to describe people who make things, usually as a hobby, sometimes as a profession. These things range from homemade LED lamps to robotic drawing machines and everything in between. Many of the projects that Makers create use microcontrollers; a testament to the more than three million Arduino devices sold worldwide. However, most of these projects are physically large in size. They are powered either by battery packs or plugged directly into the wall. Most professional electronic devices come in small sleek packages and are powered off tiny internal rechargeable batteries. Makers need a way to make their projects small and sexy too. Currently there is no easy way to fit an entire microcontroller project built at home, along with a power management system, and a battery into a small sleek enclosure. That's where Boosty-bit comes in.

Boosty-bit is a very small dc-dc power converter that allows users to power their projects off a single battery. This allows them to fit their entire project inside of a tiny portable enclosure. It comes equipped with an ATtiny85 microcontroller on board to help springboard the development of at-home projects.

As a "maker" myself, I always wanted an easy way to power my projects away from a bench-top power supply. I wanted to bring my projects with me wherever I went and show them to people. But unfortunately, this was not as easy as I thought it should be. I searched the Internet for such a product, but always came up empty handed– at least, until now.

Requirements and Specifications

1) The DC-DC converter must also be able to source 250mA.
   (Boosty-bit be able to power a microcontroller and 10 LEDs entirely off a single alkaline battery.)
2) DC-DC converter must run all the way down to 0.8 volts and boost up to 3.3 volts.
3) Boosty-bit must be able to fit inside a large pen or marker along with microcontroller and other components.
4) Must cost $10 or less.
5) Should be able to use the DC-DC converter portion of Boosty-bit separately from the microcontroller side.
6) Design should be user friendly, so that it can be added on to existing projects easily.

Design

At it's core, Boosty-bit is a DC-DC converter for small microcontroller projects. It uses a single alkaline cell to output 3.3v @ 250mA. Although Boosty-bit is intended for use with just about any microcontroller, it comes with an ATtiny85 already attached. However, the ATtiny portion of the PCB is distinct from the power management side. This allows the user to snap off the microcontroller side, and use it separately from the DC-DC converter. It also allows the user to choose another microcontroller altogether to use with Boosty-bit.

Aside from the power output capability of the Boosty-bit, physical size was the focus of the design. Being able to build and fit an entire project into a pen-sized enclosure was the main goal from the get-go.

The process of making the prototype of Boosty-bit was done in the "maker" spirit. I employed at-home techniques for making the PCB; pick-and-placing components, reflowing soldering, and testing. After all, the goal of the project was to make something for "makers" like me.

Hardware

The main feature of the Boosty-bit is the DC-DC conversion, so, the first step in designing it was to select a dc-dc converter chip based on the desired specifications. After selecting a converter, auxiliary components were chosen to support it's function. I used four large tantalum capacitors in parallel to minimize ripple and ESR. Next I drew up a schematic in Eagle CAD using the components I selected, as shown in Figure 1. With the boost converter portion of the PCB design completed, I appended traces for a microcontroller and breakout pin section to the board. The Atmel ATtiny85 was chosen as the default microcontroller to be used with Boosty-bit, however, the microcontroller section of the board is removable, thus another device could be used.

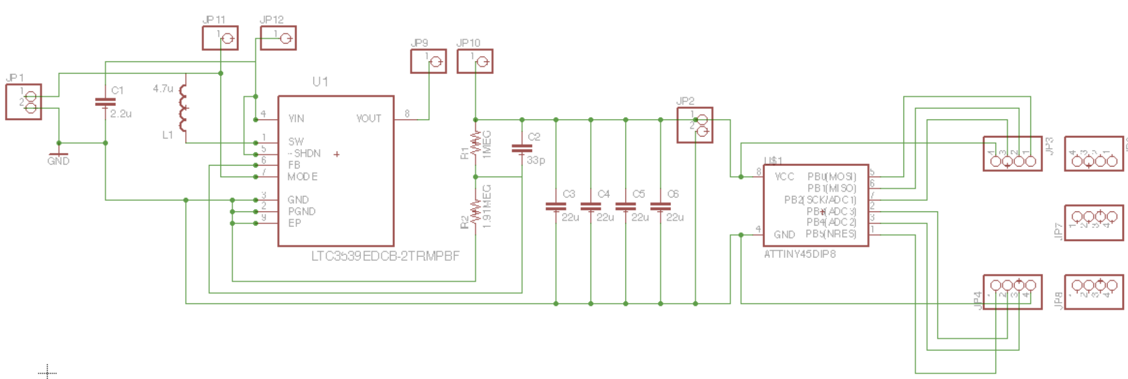


Figure 1 - Boosty-bit Schematic for Single Layer PCB

After the schematic was created, a layout for a printed circuit board was made. The PCB design is shown in Figure 2.

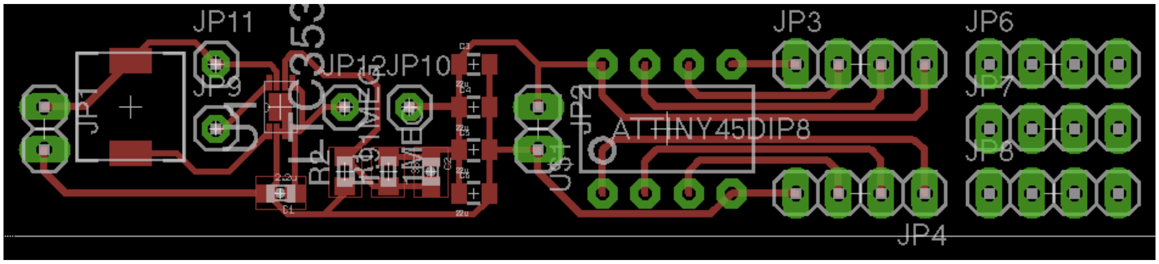


Figure 2 - Boosty-bit Single Layer Printed Circuit Board Layout

The PCB design was then transferred to a copper coated board and etched. The image transfer and etching process was done at home using the toner transfer method. Toner transfer is the process of heating an image, printed with a laser printer, onto a copper surface. This process makes it possible to quickly prototype PCBs at home. However, it requires a lot of trial and error to make it work, especially with components as small as the ones used in this project. The etched board is shown below in Figure 3.

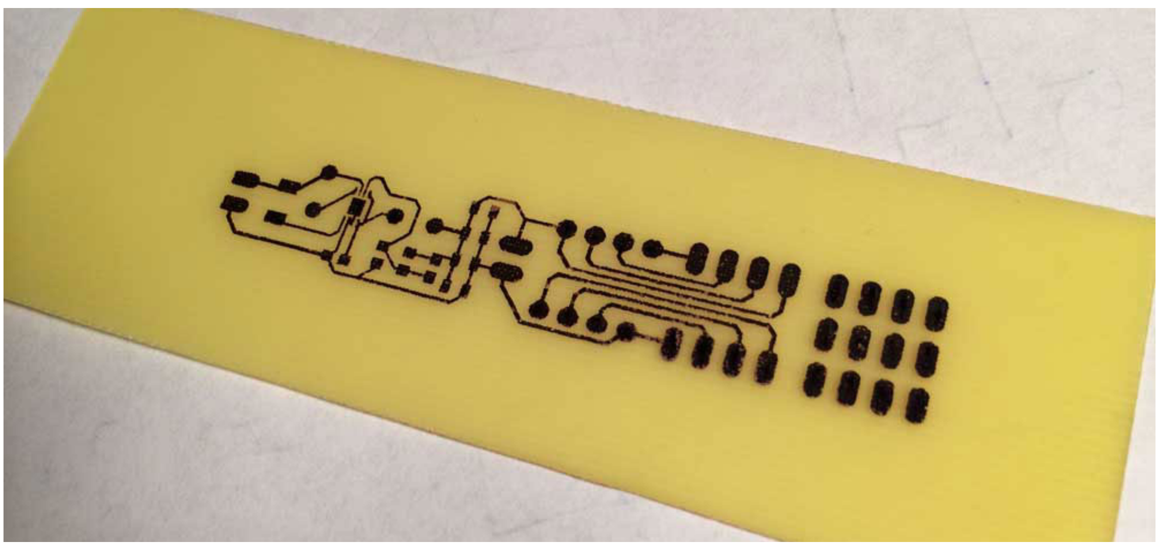


Figure 3 - Etched PCB

After etching the components were carefully placed and soldered to the board. The process of placing and soldering components was also done at home. Solder paste was applied to the pads by hand using a fine tipped rod, a tedious process that requires much patience. Solder reflow was done in a toaster oven that had been modified with a relay, thermocouple, and microcontroller to follow a temperature profile. Figure 4 shows the PCB populated with surface-mount components next to a dime for scale.

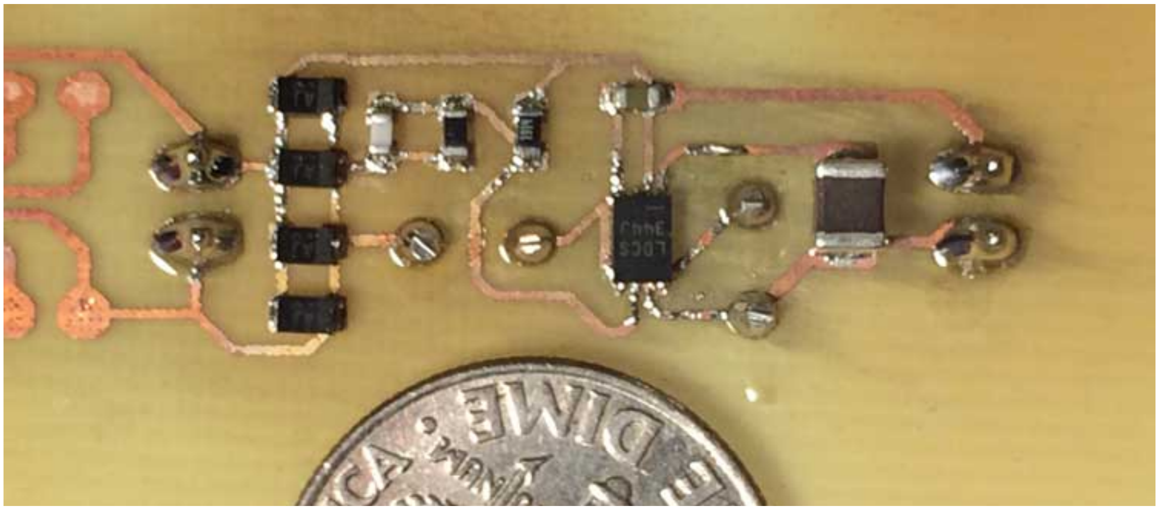


Figure 4 - Printed Circuit Board Assembly (PCA)

The last part of the design was to drill holes for the microcontroller and breakout pins for testing. This was done with a rotary tool and tiny drill bits. The through-hole components were then soldered on by hand.

Testing

Upon completion of the first prototype, a quick sanity check was done. A 1.5-volt battery was connected to the input terminals of the Boosty-bit and the output voltage was measured.

$$V_{Nominal} = 3.33V$$

After seeing that the system was working, I setup a microcontroller and 3 LEDs to test it out. That seemed to work fine. However, the load regulation testing did not turn out so well. Trying to draw 250mA from the device overloaded it and the output voltage plummeted. At 200mA and 150mA the same thing happened. The device ended up only being able to sustain around 100mA. All the components and are rated for much higher loads, but somehow it is still being held back from its full potential. My intuition tells me that the inductor may have become saturated, but more testing is needed to be sure. In revisions I may need to swap out components to make it work up to 250mA.

Testing at 100mA as full load, the system performed well. Load regulation was 0.3V/V and Maximum ripple was 443mV.

Load Regulation:

$$\frac{|V_{NoLoad} - V_{FullLoad}|}{V_{NoLoad}} * 100 = LoadRegulation$$

$$\frac{|3.33 - 3.44|}{3.33} * 100 = 0.3\frac{V}{V}$$

Voltage Ripple:

$$Minimum\ Ripple\ =\ 46mV$$

$$Maximum\ Ripple\ =\ 443mV$$

Future Work

The first prototype of the product works very well. However, there are a few modifications that need to be made on the original design. The only major issue with the first design was that the trace layout for the ATtiny microcontroller was mirrored from how it should have been. To get around this I soldered the through-hole microcontrollers pins from the same side of the PCB as it was placed as if it were a surface-mount part.

In my next revision I will switch to a dual-layer PCB design and use a manufacturing company to make the boards and populate the components. I will also switch to a surface mount version of the ATtiny microcontroller. These changes will shrink the size of the Boosty-bit converter by more than 50%. Additionally, I would like to seek out less expensive components to get closer to my end-user price goal.

Using a professional manufacturing company will greatly reduce the cost per unit. It will also allow me to have custom shaped PCBs. A custom shaped PCB can have perforations that allow the different segments of the board broken apart and used individually.

In order to get the product onto the market, I might do a Kickstarter or try to get it picked-up by Sparkfun or Adafruit.

Appendix A – References

[1] ATMEL, "High Performance, Low Power Atmel®AVR® 8-Bit Microcontroller" ATtiny85 datasheet, Feb. 2005 [Revised Feb. 2013].

- Microcontroller datasheet for Boosty-bit

[2] Linear Technology, "2A, 1MHz/2MHz Synchronous Step-Up DC/DC Converters" LTC3539/LTC3539-2 datasheet, Jan. 2008 [Revised Feb. 2013].

- DC-DC converter chip datasheet for the Boosty-bit

[5] Texas Instruments, "Mixed Signal Microcontrollers," MSP430G2x44 datasheet, March. 2013 [Revised October 2013].

- Another low cost microcontroller option that could be used in place of the ATtiny.

[6] Broadcom, "ARM Peripherals," BCM2835 datasheet, January. 2012

- This ARM microcontroller from Broadcom is yet another low cost option for use in my design.

Appendix B – Bill of Materials

Table 1 - Bill of Materials

Item #	Name	Description	Quantity	Value	Labels
1	LTC3539	DC-DC Boost Converter	1	N/A	U1
2	Inductor	SMD-2	1	4.7uH	L1
3	Capacitor	Ceramic SMD	1	2.2UF	C1
4	Capacitor	Ceramic SMD	1	33pF	C2
5	Capacitor	Tantalum SMD	4	22uF	C3-C6
6	Resistor	SMD	1	1M	R1
7	Resistor	SMD	1	562k	R2

Appendix C – Analysis of Senior Project Design

Table 2 – Analysis of Senior Project Design

Project Title: Boosty-Bit
Student's Name: Timothy Grijalva
Advisor's Name: Dr. Bridget Benson

• **1. Summary of Functional Requirements:**
Device uses a AA or AAA battery as input and outputs 3.3v at up to 250mA.

• **2. Primary Constraints:**
Efficiency of power conversion is a major constraint. Not many dc-dc converter chips on the market operate in this range because most are intended for use with lithium-ion cells.

• **3. Economic Evaluation:**

Component	Units Required	Cost Per Unit	Total Cost
PCB	1.00	5.00	5.00
Boost Converter IC	1.00	6.11	6.11
Inductor	1.00	0.23	0.23
Input Capacitor	1.00	0.12	0.12
Feedback Capacitor	1.00	0.10	0.10
Output Capacitor	4.00	1.03	4.12
Feedback Resistor	2.00	0.10	0.20
Solder Paste	0.05	12.20	0.61
Headers	1.00	0.10	0.10
Labor	100.00	25.00	2500.00
		Expected Total	2516.59
		Pessimistic Total	5033.18
		Optimistic Total	1677.73
		Formula Total	2796.21

Manufacture of such a product will require materials and produce waste similar to any other home electronics product although on a much smaller scale due to the devices size. Product life should be at least 5 years. Projected cost of design and implementation is expected to be around three thousand dollars. Product cost per unit is expected to be around fifteen dollars.

There are no additional costs at this time. The project is not expected to make any significant amount of money. The creator of the product profits. Products emerge six months after designs are finalized. Products have an expected lifecycle of five to ten years. There are no ongoing costs for users. Development time is six months.

Gantt Chart of Project Timeline:

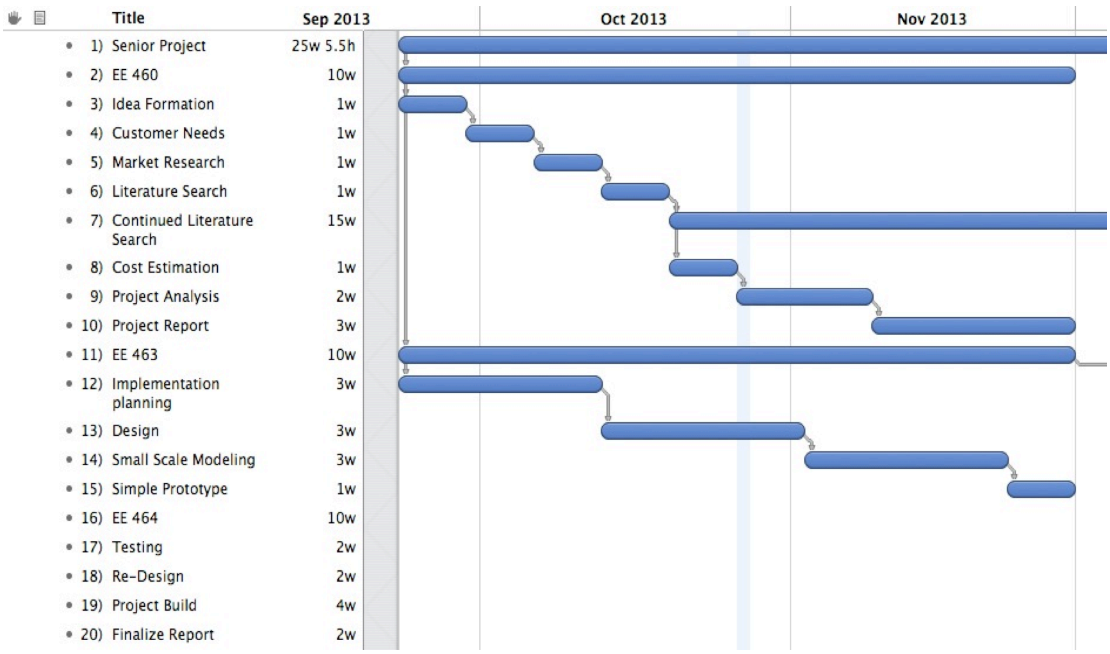
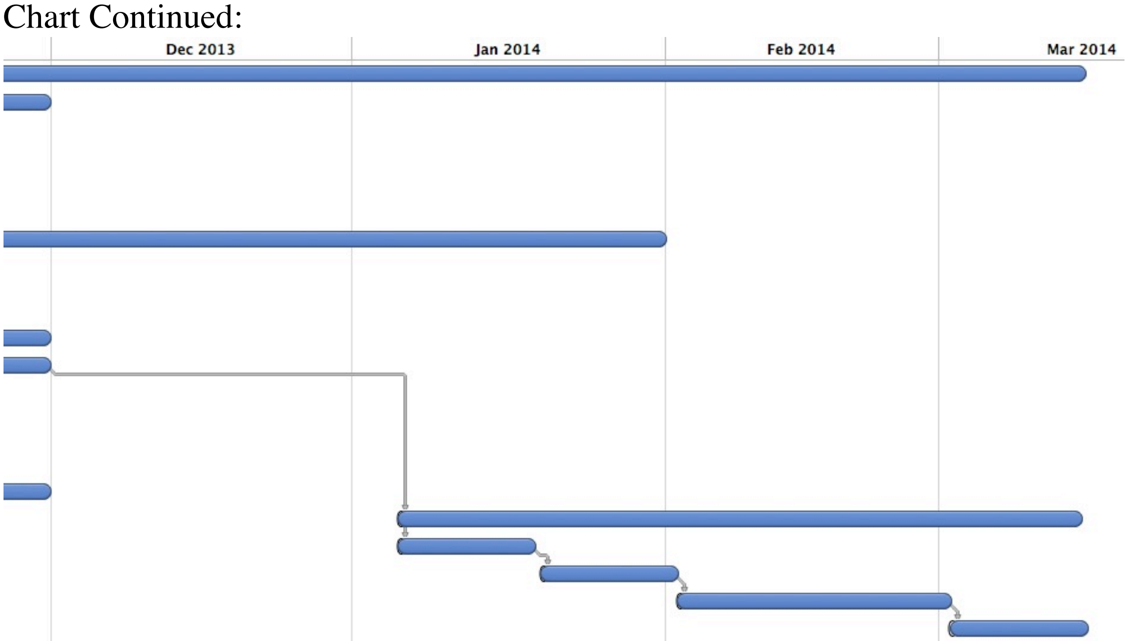


Chart Continued:



• 4. If manufactured on a commercial basis:
Approximately one thousand devices are expected to be sold. Each device costs ten dollars to manufacture. The purchase price is twenty dollars per unit.

• 5. Environmental:
The environmental effects of manufacture are pollution due to electronic waste and shipping the manufactured product from china and to users. However, the product had been designed with resources in mind and the total waste material has been minimized. Energy of transportation and manufacture along with plastic are the resources used. Manufacturing the product produces waste and carbon dioxide. The product does not impact other species, but the pollution produced from manufacture does.

• 6. Manufacturability:
A contractor in China will do Manufacturing. Working with the contractor to insure quality standards are met is the largest challenge anticipated.

• 7. Sustainability:
The device does not require any maintenance and should function for at least ten years. Resources consumed due to production of the product are energy and plastic. The product cannot be upgraded once manufactured.

• 8. Ethical:
Under the ethical framework of self-interest, the product benefits the life of the user. It improves the enjoyment they get from making things. The product does not go against the IEEE code of ethics.

• 9. Health and Safety:
The product should be manufactured to ROHS standards to make it safe for users to keep in their home.

• 10. Social and Political:
Manufacture and shipping uses energy and materials. Disposal puts electronic waste into landfills. While the product is in service it uses very little electricity. The product impacts people who buy the product and the producer of the product.

• 11. Development:
Tools used for designing the product include schematic software, PCB manufacture and circuit simulators. For testing, scopes, logic analyzers and multi-meters are used.