Smart USB Charger

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New EE Entrepreneurial CAPSTONE

Introduction

The main objective of this project is to design and implement a Smart USB charger that has three USB ports. It is called “smart” because the charger will be able to charge the higher priority phones at almost full rate before moving on to lower priority phones. With that function, this USB charger will fully charge several phones much faster than traditional USB chargers having only one power supply.

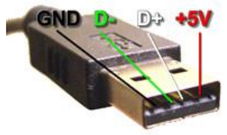

Figure 1. Four pins of a USB port

Initial Approaches

We first wanted to build a good understanding on how a USB charger actually works. With the help of Plugable Technology, we learned that D+ and D- pins of a USB port can signal how much current the charger can provide and that we can manipulate the D+ and D- voltage signals to control the charging rate (See **Figure 1**).

	A	B	C	D	E	F	G
1	Pins	1	2	3	4		
2	USB Standard Signal	VCC	D -	D +	GND		
3	Color						Signal
4	Amazon A00810-01 (4.9V 0.85A)	4.92	0.00	0.00	0.00		DCP
5	Apple A1102 (5.0v 1.0A)	5.13	2.06	2.76	0.00		Apple 1A
6	Apple A1265 (5.0v 1.0A)	5.12	2.03	2.73	0.00		Apple 1A
7	Apple A1401 (5.2V 2.4A)	5.19	2.77	2.77	0.00		Apple 2.4A
8	Dell DA24NM130 (5.0V 2.0A or 19.5V 1.2A)	5.02	0.00	0.00	0.00		DCP
9	Dell HA10USNM130 (5.0V 2.0A)	5.31	0.00	0.00	0.00		DCP
10	Generic 30pin Car Charger	5.19	2.06	2.07	0.00		Apple 500mA
11	HP LPS AC/DC Adapter	5.19	2.79	2.79	0.00		Proprietary
12	Iconia W4 "Chicony" W12-010N3A (5.35V 2.4A)	5.36	0.00	0.00	0.00		DCP
13	Jawbone SPA-K901 (5.0V 0.55A)	5.04	0.00	0.00	0.00		DCP
14	LG STA-U12WR (5.1V 0.7A)	5.11	0.00	0.00	0.00		DCP
15	Motorola DC4050US0301 (5.1V 0.85A)	5.17	0.00	0.00	0.00		DCP
16	PB-12K2 1.0A Port	5.16	2.04	2.74	0.00		Apple 1A
17	PB-12K2 2.1A Port	5.16	2.74	2.08	0.00		Apple 2.1A
18	Samsung EP-TA10JWE (5.3V 2.0A)	5.35	1.24	1.24	0.00		Samsung
19	Samsung ETA-P11JBE (5.0V 2.0A)	5.03	1.25	1.25	0.00		Samsung
20	Samsung ETA-U90JWE (5.0V 2.0A)	5.10	1.27	1.27	0.00		Samsung

Figure 2. Data collection chart given by Plugable

Figure 2 shows that each kind of phones has different voltages on D+ and D-. We built our test circuit using a 5V power supply for Vbus and some resistors to simulate different charging signals on D+ and D-. By using a voltage divider, we assigned 2.7 V for D+ and 2.0 V for D-. Then, we measured current on Vbus to see if the current was about 1A when the circuit was charging our iPhone. It turned out that we obtained correct test result that matched the data chart.

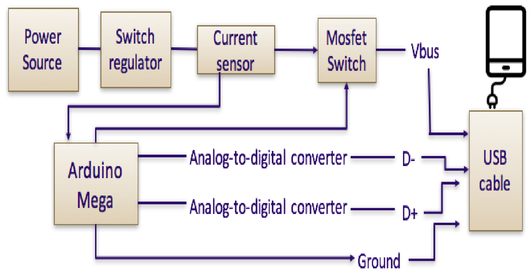

Figure 3. A block diagram of our Smart USB charger

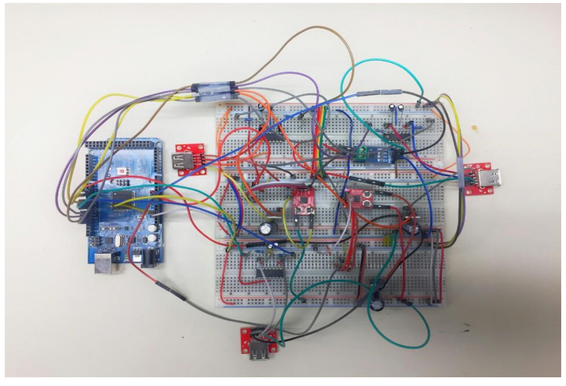

Figure 4. Picture of our first Smart USB Charger prototype

Methodology

We used an Arduino Mega Board and C language to design and implement our **priority charge behavior module**. This module should select the best charging mechanism for different phones or devices by automatically adjusting D+ and D- signals until the maximum charging rate is found.

We used Arduino to generate PWM output. Then, we built two analog-to-digital-converter (**Figure 6**) for each of three USB ports to send converted signals (DC) to D+ and D- through analog output pins of Arduino board. By changing the duty cycle of PWM (**Figure 5**), we could set the limit of current flowing through phones being charged.

We also built a **switch regulator circuit** (see **Figure 7**) to regulate the output voltage (5V) of each port. We used a controller chip, which has a feedback function. The feedback pin can detect the voltage output and adjust the switching wave with different duty ratio to maintain a constant voltage output. We increased duty cycle to increase the output voltage and vice versa.

Duty Cycle	Current (A)
100 %	0.97
78 %	0.75
59 %	0.65
39 %	0.5
31 %	0.4
Below 31 %	Stop charging

Figure 5. The relationship between duty cycle of PWM and the amount of current when our circuit charges an iphone (maximum current rate is 1 A)

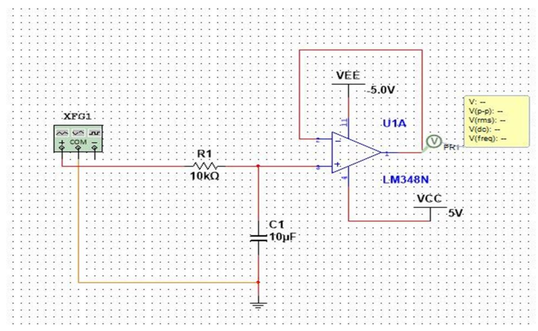

Figure 6. Schematic of analog to Digital converter

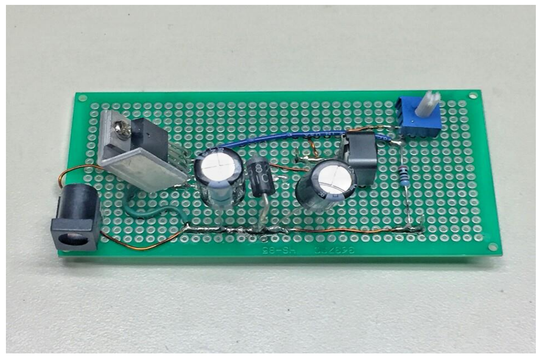

Figure 7. Switch Regulator Circuit

Figure 8. Measurement of voltage (Vbus) and current while charging an iPhone

Results

- We are able to detect/identify different kinds of phones by using our C program and a current sensor.
- We conducted several testing procedures to verify that our charger circuit assigns optimized voltage signals to D+ and D- lines for maximum charging rate by using Arduino output pins.
- We did soldering work to have better, stable connections.
- We built a Mosfet current switch for safety purpose
- Our prototype successfully demonstrate the priority charge behavior (charge the higher priority phones at almost full rate before moving on to lower priority phones)

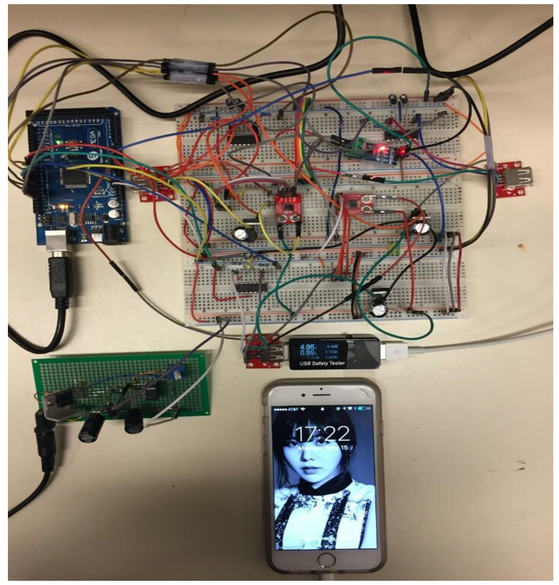

Figure 9. Picture of the whole circuit of our prototype

Discussion

The challenge of this project was that the actual charging behavior of different phones or devices was often unpredictable and sometimes disappointing because devices themselves decide how much current to draw and manufacturers have not settled on a single standard. It required us to test our module with as many different devices as possible and to collect test results for future references.