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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

USB 3.0 Outlet

Project Proposal

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Contents

1 Introduction

The project aims to address the growth of external DC converters for consumer products. The objective of this project is to modify an AC wall outlet to include two DC USB ports. One of the DC USB ports will be a lower power, 5V 5A, standard USB 3.0 port; the other one will be a high power, 12V 15A, modified USB 3.0 port. These additional USB ports would eliminate the need for DC converter outside the wall outlet. The project was selected because of the group's common interest in power electronics. It also has a commercial viability and implementation of the product to an existing wall outlet would be simple. This product will promote the standardization of DC appliances. It will also further the transition to green technologies by removing the need for wasteful external converters and replacing them with higher efficiency permanent converters.

Objective:
The modified wall outlet intends to include USB compatibility and maintain a simple installation process for the users. The product will be designed to achieve a high efficiency during the conversion between AC to DC power and DC voltage levels. It will also provide a more ascetically pleasing environment for the user by eliminating bulky external DC converters.

Consumer Benefits:

- Uses less energy
- Saves money on power bill
- Quieter appliances
- User-friendly
- Less "wall warts" (external DC converters)

Product Features:

- Two USB ports with various power levels
- In-wall installation
- High efficiency
- Two 120V 15A AC outlets
- Eliminated need of additional power converter
- Simple installation process

2 Design

2.1 Block Diagram

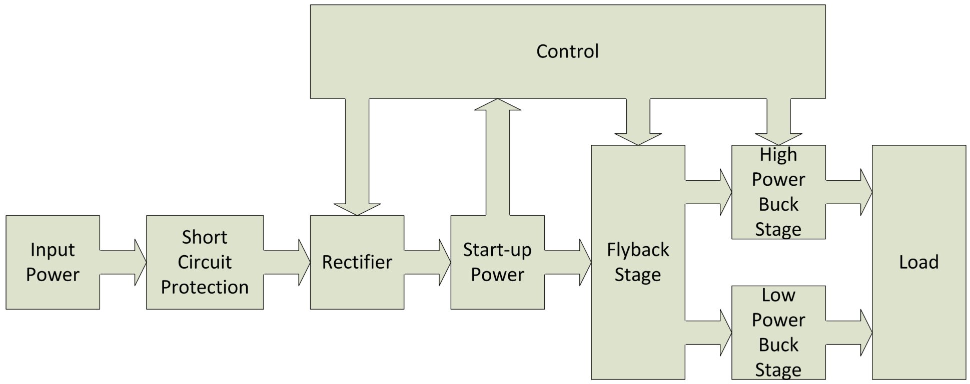

Figure 1: Block Diagram

2.1.1 Block Descriptions

Control The control algorithms will be implemented using a TI MSP430. Four control signals will be needed: flyback switching signal, high power and low power buck switching signals, and short circuit protection shutoff signal.

Rectifier The rectifier will be implemented using Schottky diodes for reduced voltage drop and higher efficiency.

Start-up Power The start-up power unit will utilize the AC power sources along with a linear regulator to provide initial power required by the micro controller. After the system has reached steady state the unit will switch to a DC power sources which is provided by the low power buck converter. The change in power sources will increase efficiency for the overall system.

Short Circuit Protection The short circuit protection circuit will limit the amount of output current during short circuit conditions. The circuit will detect a short circuit and power down the outlet. This added protection will increase the safety of the outlet.

Flyback Stage A property of a flyback converter is galvanic isolation between the output and input power which will protect the system from current surges. The converter includes a coupled inductor that maintains properties of an ideal transformer and provides turns ratio advantages. The flyback also steps down the DC voltage before the voltage is the input into the buck converter. By stepping the voltage in two stages, the circuit components are able to be sized down. It also provides a high power factor for the system.

High Power Buck The high power buck converter will step down the voltage from 25V to 15V. The converter also helps with line regulation and ripple.

Low Power Buck The low power buck converter will step down the voltage from 25V to 5V. Similar to the high power buck converter, the lower power converter also helps with line regulation and ripple.

Load The system load will be a varying electronic load for testing purposes. The final demo load for the low power circuit will be charging three different cell phones including an Android phone and an iPhone 4. The final demo load for the high power circuit will be an electric drill.

2.2 Performance Specifications

Input voltage: AC 120V 15A 60Hz
Two USB 3.0 ports: 5V 5A and 12V 15A output
Two output voltage: AC 120V 15A
Switching frequency: 100kHz
Load regulation: 0.5%
Max/startup current: 10A
Output ripple: 1%
Power factor: 0.85
Efficiency: 85%
Charge all mobile phones that accept USB power

3 Verification

3.1 Testing Procedures

Output voltage and current ripple will be measured by utilizing a differential probe, a current probe and an oscilloscope in AC coupling mode. The output ripple varies along with the changing load and frequency. A graph will be produced to reveal the relationships between these properties.

Load regulation is defined in (1). Using an electronic load in constant current mode, the circuit will be tested under full load and no load conditions.

$$\%Load\ Regulation = \frac{V_{out(minload)} - V_{out(fullload)}}{V_{out(nom)}} \tag{1}$$

The circuit will be build modularly, with each part being examined individually for specific performance analysis. The rectifier will be tested to establish a stable DC input to the flyback. While the flyback will be analyzed to ensure the correct sizing of the components. The flyback must also provide a 20V DC voltage to the buck converters. The buck converters will be examined for the output current and voltage ripple to verify that they are within the tolerance specified by the performance specifications.

3.2 Tolerance Analysis

The functionality of the circuitry is dependent on the switching frequency of the flyback converter. Along with it, the switching frequency is inversely proportion to the size of the inductor in the flyback circuit. If the frequency is too small, the inductor will saturate and act as a short circuit. If the frequency is too large, the losses due to heat will increase dramatically. The current components are selected to function at the nominal switching frequency of 100 kHz. In order to ANALYZE the system responsiveness, the frequency will be varied from 10 Hz to 1 MHz.

In addition to the frequency tolerance analysis, the gate drive circuitry will contain various pot resistors to determine the output current to gain optimal control of the MOSFET for the flyback converter. The initial stage of the gate driver circuit will be based on the information given on the data sheet. Afterward, a potentiometer will be used to determine the optimal response from the driver.

4 Cost and Schedule

4.1 Labor

Table 1: Labor Cost

Name	Rate	Hour	Total = Rate * Hour * 2.5
Cindy Fok	$50/hr	180	$22,500
Andrew Moruzi	$50/hr	180	$22,500
Tyler Neyens	$50/hr	180	$22,500
		Total	$67,500

4.2 Parts

Description	# on PCB	Supplier	Cost/Per Unit	Total Cost
Rectifier				
Diode Schottky	4	Digikey	$3.20	$12.80
Flyback Stage				
Inductor Core	1	Supplied in Lab	-	-
Inductor Wire		Supplied in Lab	-	-
MOSFET	1	Digikey	$3.43	$3.43
High Side Gate Driver	1	Supplied in Lab	-	-
Bootstrap Diode	1	Supplied in Lab	-	-
Bootstap Capacitor	1	Supplied in Lab	-	-
Output Capacitor	1	Supplied in Lab	-	-
Heat sink	1	Supplied in Lab	-	-
Buck Stage				
Inductor	2	Supplied in Lab	-	-
Output Capacitor	2	Supplied in Lab	-	-
Low Buck-5.5V to 36V Input, 5A	1	Digikey	$3.25	$3.25
High Buck-Wide Input Synchronous	1	Digikey	$2.70	$2.70
Control				
Micro controller	1	Digikey	$1.56	$1.56
Relay	1	Digikey	$1.86	$1.86
Output				
USB 3.0 Female	2	Digikey	$2.80	$5.60
USB 3.0 Male	2	Digikey	$3.28	$6.56
Banana Plugs Female	8	Digikey	$0.70	$5.60
Banana Plugs Male	8	Digikey	$1.62	$12.96
AC Outlet	1	Menards	$0.39	$0.39
Total Parts Cost				$56.71

Total Project Cost = $67,600 + $56.71 = $ 67,656.71

4.3 Schedule

Week	**Description of Task**	**Group Member**
1/16	**Initial Posts**	**Class Dates**
	Find partner and brainstorm ideas	Cindy Fok
	Find partner and brainstorm ideas	Andrew Moruzi
	Find partner and brainstorm ideas	Tyler Neyens
1/23	**None**	**Class Dates**
	Email Prof. Carney about addition to project	Cindy Fok

	Topology research	Andrew Moruzi
	Initial simulations	Tyler Neyens
1/30	**RFA Due, Project Page Update, Schedule Submitted**	**Class Dates**
	Research section/design, Learn MSP430	Cindy Fok
	Power ratings, proposal	Andrew Moruzi
	Inductor calculation, part selection	Tyler Neyens
2/6	**Proposals Due, TA Meeting**	**Class Dates**
	Rectifier, Finalize BOM, Cont. MSP430	Cindy Fok
	Start Flyback on breadboard, Gate drivers	Andrew Moruzi
	Final simulation, Start Design Review	Tyler Neyens
2/13	**TA Meeting**	**Class Dates**
	Design Review final, Controls	Cindy Fok
	PCB Schematic Design	Andrew Moruzi
	Finish Flyback, Start Buck on Breadboard, Gate drivers	Tyler Neyens
2/20	**Design Reviews, TA Meeting**	**Class Dates**
	Finish Buck on Breadboard	Cindy Fok
	Eagle Part Design/Library	Andrew Moruzi
	Final Breadboard Testing	Tyler Neyens
2/27	**TA Meeting**	**Class Dates**
	Order PCB 1.0 from 4PCB	Cindy Fok
	Start SC Protection	Andrew Moruzi
	Finalize PCB Board Layout	Tyler Neyens
3/5	**TA Meeting**	**Class Dates**
	IPR, Finish SC Protection	Cindy Fok
	IPR, Start up power	Andrew Moruzi
	IPR, Test SC Protection	Tyler Neyens
3/12	**Individual Progress Reports, TA Meeting**	**Class Dates**
	Order PCB 2.0 from 4PCB	Cindy Fok
	Test PCB 1.0	Andrew Moruzi
	Finalize PCB 2.0, Test Start up power	Tyler Neyens
3/19	**Spring Break**	**Class Dates**
3/26	**Mock-up Demos, TA Meeting**	**Class Dates**
	Control slides	Cindy Fok
	Test slides	Andrew Moruzi
	Design slides	Tyler Neyens
4/2	**Mock-up Presentations, TA Meeting**	**Class Dates**
	Modify USB cord	Cindy Fok
	Circuit Housing	Andrew Moruzi
	Custom Load	Tyler Neyens
4/9	**Last Day for Final PCB, TA Meeting**	**Class Dates**
	Presentation	Cindy Fok
	Load	Andrew Moruzi
	Demo	Tyler Neyens
4/16	**Demo and Presentation Sign-up Closes, TA Meeting**	**Class Dates**
	Final Paper - Intro, cost, conclusion	Cindy Fok
	Final Paper - design procedure, details	Andrew Moruzi
	Final Paper- testing, verification	Tyler Neyens
4/23	**Demos, Presentations, TA Meeting**	**Class Dates**
	Final Paper Review - Intro, cost, conclusion	Cindy Fok
	Final Paper Review - design procedure, details	Andrew Moruzi
	Final Paper Review - testing, verification	Tyler Neyens
4/30	**Presentations, Final Paper, Checkout, Lab Notebooks**	**Class Dates**