Solar Powered Beach Chair

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Introduction

- Uses the power of the sun to provide the user with a USB ready charging station

- The Solar Powered Beach Chair powers your phone, your tablet, and keeps your drink cool all without you having to worry about sand and water interfering with your electronics!

Features and Benefits

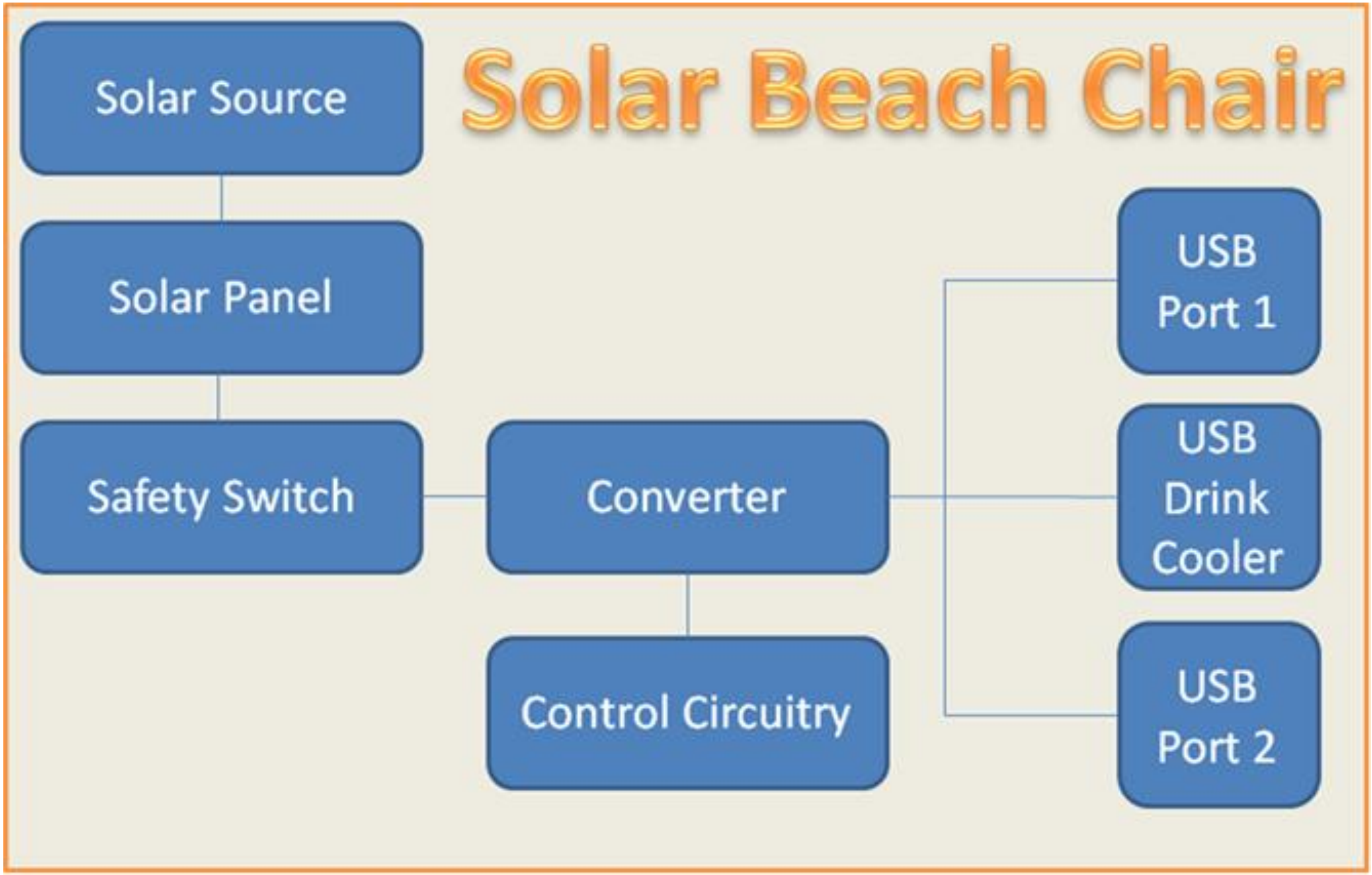
Features

- On/Off switch
- Three USB charging ports
- Drink Cooler
- 50 W solar panel integrated on the chairs canopy
- Durable, water resistant, and sandproof to ensure longevity

Benefits

- Charge devices while soaking up the sun
- Solar canopy provides the user with shade
- Backpackable for easy transport
- Environmentally friendly

How it Works


Solar Beach Chair
Solar Source
Solar Panel
Safety Switch
Converter
Control Circuitry
USB Port 1
USB Drink Cooler
USB Port 2

Solar Source

Requirement

- To ensure maximum power from the solar panel, there must be $\frac{1kw}{m^2}$ of insolation available from a solar source

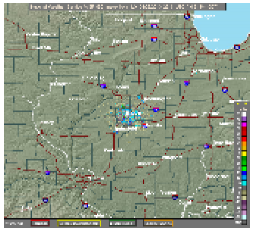
Verification

- Use isws.illinois.edu to ensure that the insolation present is at least $\frac{1kw}{m^2}$

Weather Information from the Illinois State Water Survey

Temperature: **54° F**
Wind Speed: **9 mph** (Gusts to 17 mph)
Wind Direction: **290°** (From the W)
Precipitation: **0 in.**
Relative Humidity: **36%**
Dew Point: **27° F**
Barometric Pressure: **30.17 in.** sea level pressure
Solar Radiation: **363 Watts / m^2**
4" Soil Temperature: **58° F**
8" Soil Temperature: **53° F**
Visibility: **10 mi.**

Radar



Radar image supplied by NWS

Source: http://www.isws.illinois.edu/data/wxinfo.asp

Solar Panel

Requirement

- Solar Panel must produce an output voltage of 5 V - 21.6 V and an output power of at least 50W

Source: bing.com/fluke+meter

Verification

- Use a Fluke meter to measure the output power and output voltage.

Source: http://www.sunshineworks.com/small-solar-panels-for-sale.htm

Safety Switch

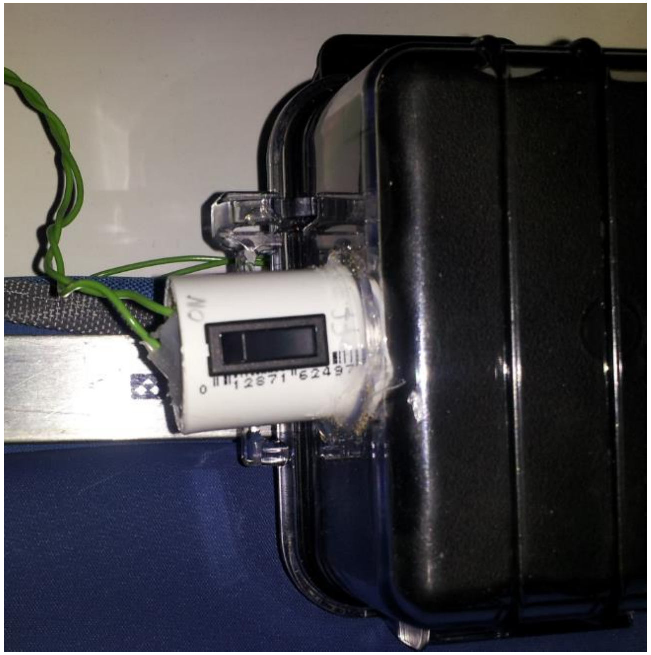
Requirement

- When switch is off, no current reaches the load, and when switch is on, current reaches the load

Source: bing.com/rocker+switch

Verification

- Ensure phone does not charge when switch is in off position and does charge when switch is on



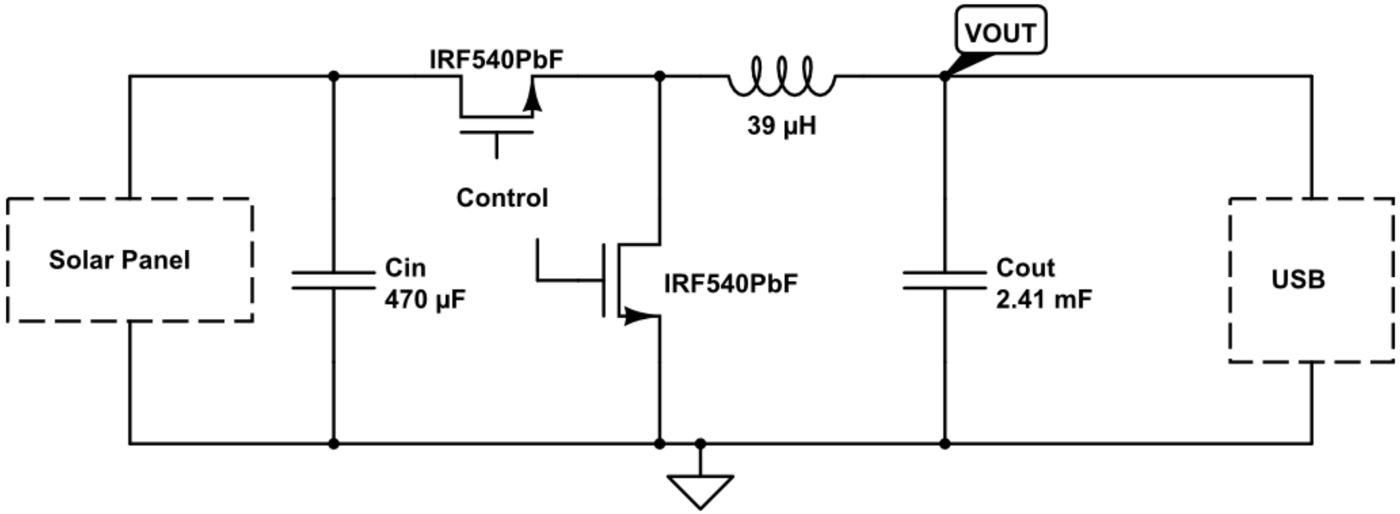
Converter

Requirement

- Output voltage must be between 4.75 V-5.25 V

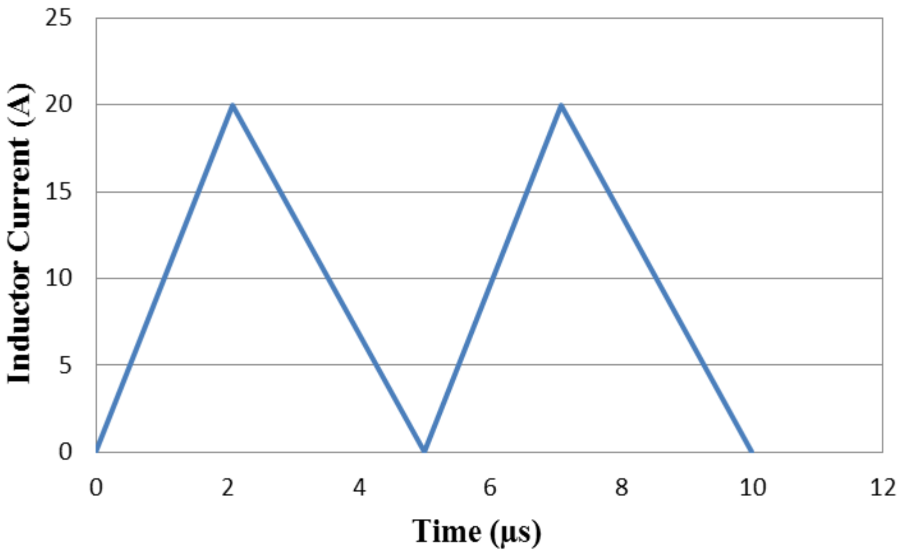
Verification

- Use a voltage probe on the output capacitor and use an oscilloscope to verify that the voltage ripple is within 4.75 V-5.25 V



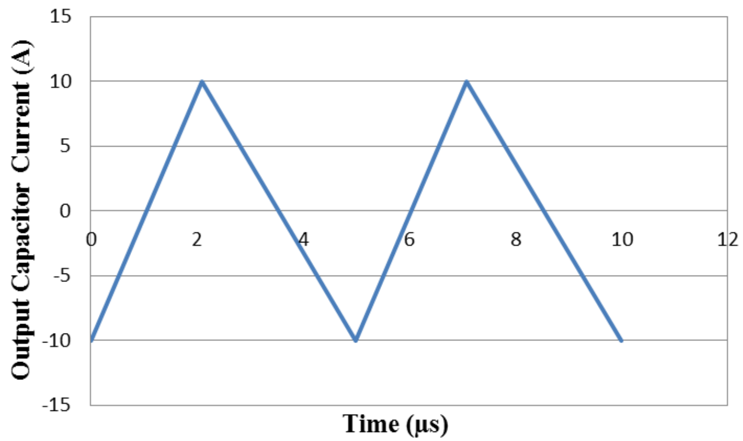
Determining Inductor Size

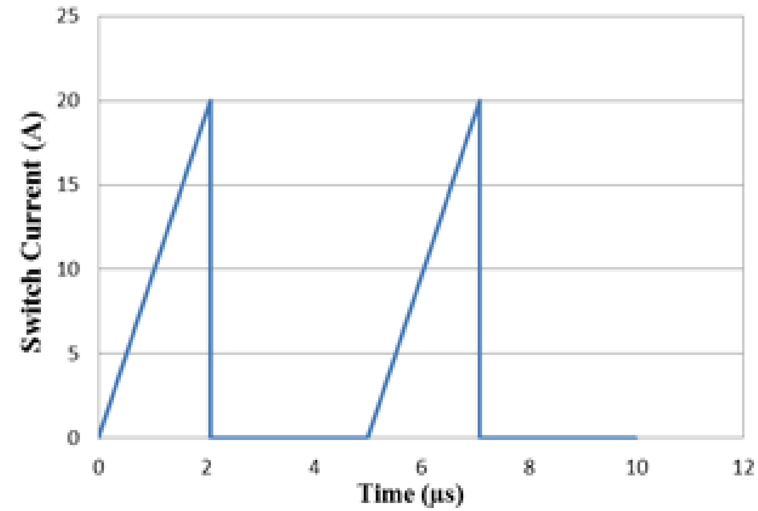
Input Voltage Range	5V - 21.6V
Output Voltage Range	4.75V - 5.25V
Output Load Range	0W - 50W



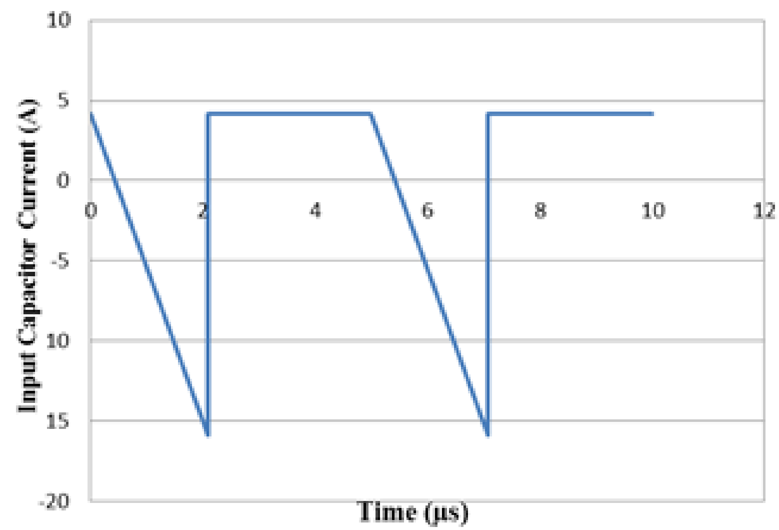
- $V_{in} = 12V, P_{in} = 50W, V_{out} = 5V, f_{sw} = 10\ kHz$
- $Duty\ Ratio = D = \frac{V_{out}}{V_{in}} = \frac{5V}{12V} = 0.417$
- Change in the Inductor Current $= \Delta I_{Lp-p} = 2 * I_{out}$
- $\Delta I_L = \frac{V_{in} - V_{out}}{L} * DT = \frac{V_{in}(1-D)}{L} * DT$
- $L_{crit} = \frac{V_{in}(1-D)D}{2 f_{sw}} * \frac{V_{out}}{P_{out}} = \frac{12(1-0.417)0.417}{2*10,000} * \frac{5}{50} = 14.59\mu H$

Current Waveforms





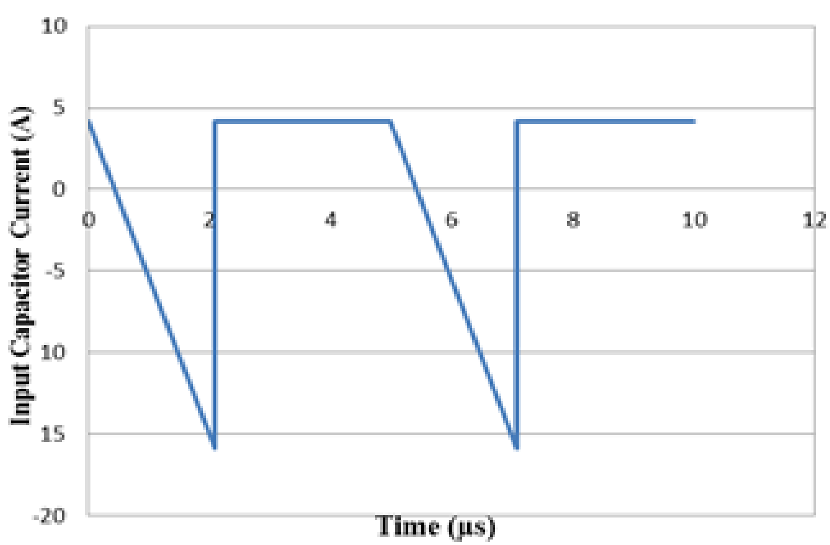
- $\boldsymbol{I_{c_{out}}}$: Average current through a capacitor is zero
- $\boldsymbol{I_{sw}}$: Switch on: $I_{sw} = I_L$
- $\boldsymbol{I_{c_{in}}}$: Switch off: $I_{c_{in}} = I_{in} = 4.17A$
  Switch on: $I_{c_{in}} = I_{in} - I_{sw}$



Determining Capacitor Sizes

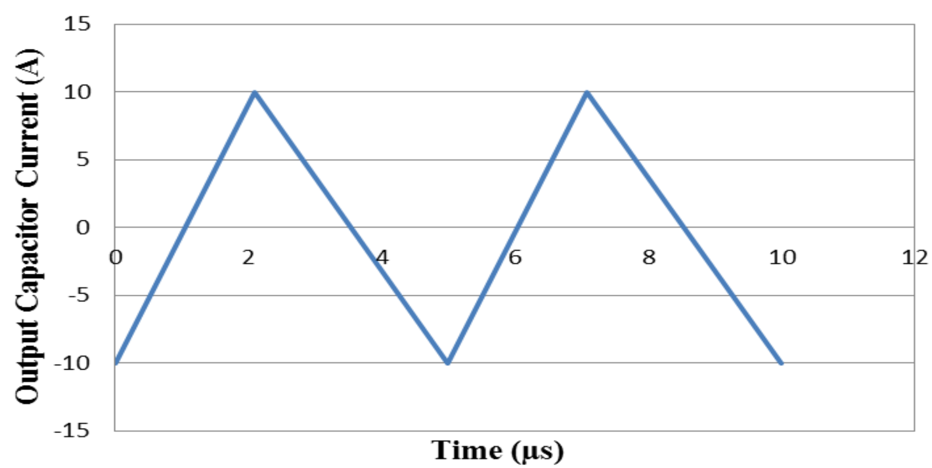
Input Capacitor Calculation

- To extract the maximum power from the photovoltaic panel, it is desired to have the input voltage ripple below $1.00V_{p\text{-}p}$.
- $\Delta V_{in_{p-p}} = \frac{\Delta Q}{Cin}$
- $\Delta Q = (1 - D)T * 4.17A + 0.5 * 4.17A * \frac{1}{20}T$
- $C_{in} = \frac{\Delta Q}{\Delta V_{in_{p-p}}} = \frac{1.268*10^{-5}}{1} = 12.68\ \mu F$



Output Capacitor Calculation

- For proper USB operation, it is required to have the output voltage ripple of the converter to be below $0.5V_{p\text{-}p}$.
- $\Delta Q = \frac{1}{2} * \frac{T}{2} * 10A = 1.25 * 10^{-5}\ C$
- $C_{out} = \frac{\Delta Q}{\Delta V_{out_{p-p}}} = \frac{1.25*10^{-5}}{0.5} = 25\ \mu F$



Efficiency Data

V_{in} [V]	I_{in} [A]	P_{in} [W]	D	V_{out} [V]	I_{out} [A]	P_{out} [W]	Efficiency [%]
10.01	0.73	7.31	0.49	4.42	1.44	6.34	86.76
12.02	0.73	8.77	0.42	4.89	1.59	7.70	87.75
10.01	0.89	8.91	0.54	4.89	1.60	7.77	87.22
10.09	0.91	9.18	0.42	5.01	1.64	8.20	89.31
17.02	0.60	10.21	0.33	5.26	1.72	9.00	88.13
10.10	1.08	10.91	0.40	5.47	1.79	9.70	88.93
12.76	0.97	12.38	0.49	5.70	1.86	10.51	84.91

Controller

Requirement

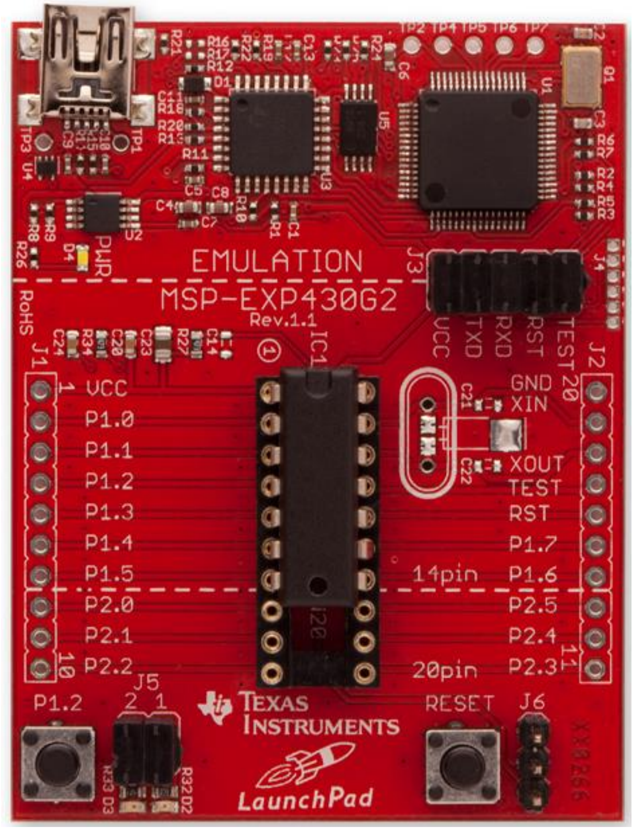
- Control circuit produces the desired PWM switching signal with the correct duty ratio

Verification

- Connect the switching signal and gate driver signals to an oscilloscope. Vary the input voltage from 10-20V and ensure the duty cycle of the signals are correct.

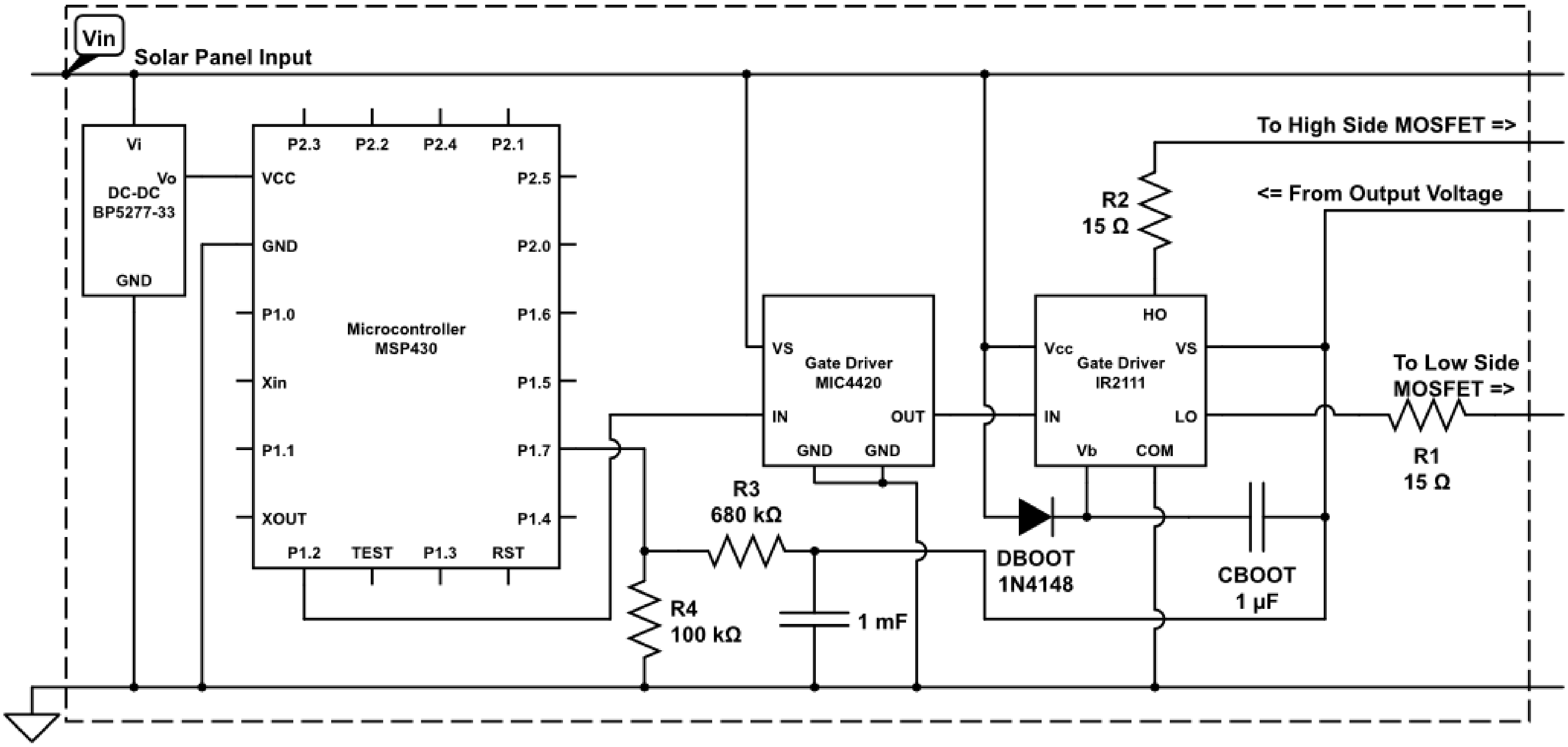
Control Circuitry

- MSP 430 Microcontroller
  - Ultra low power consumption
- Synchronous Rectification
- ~10.5kHz operation

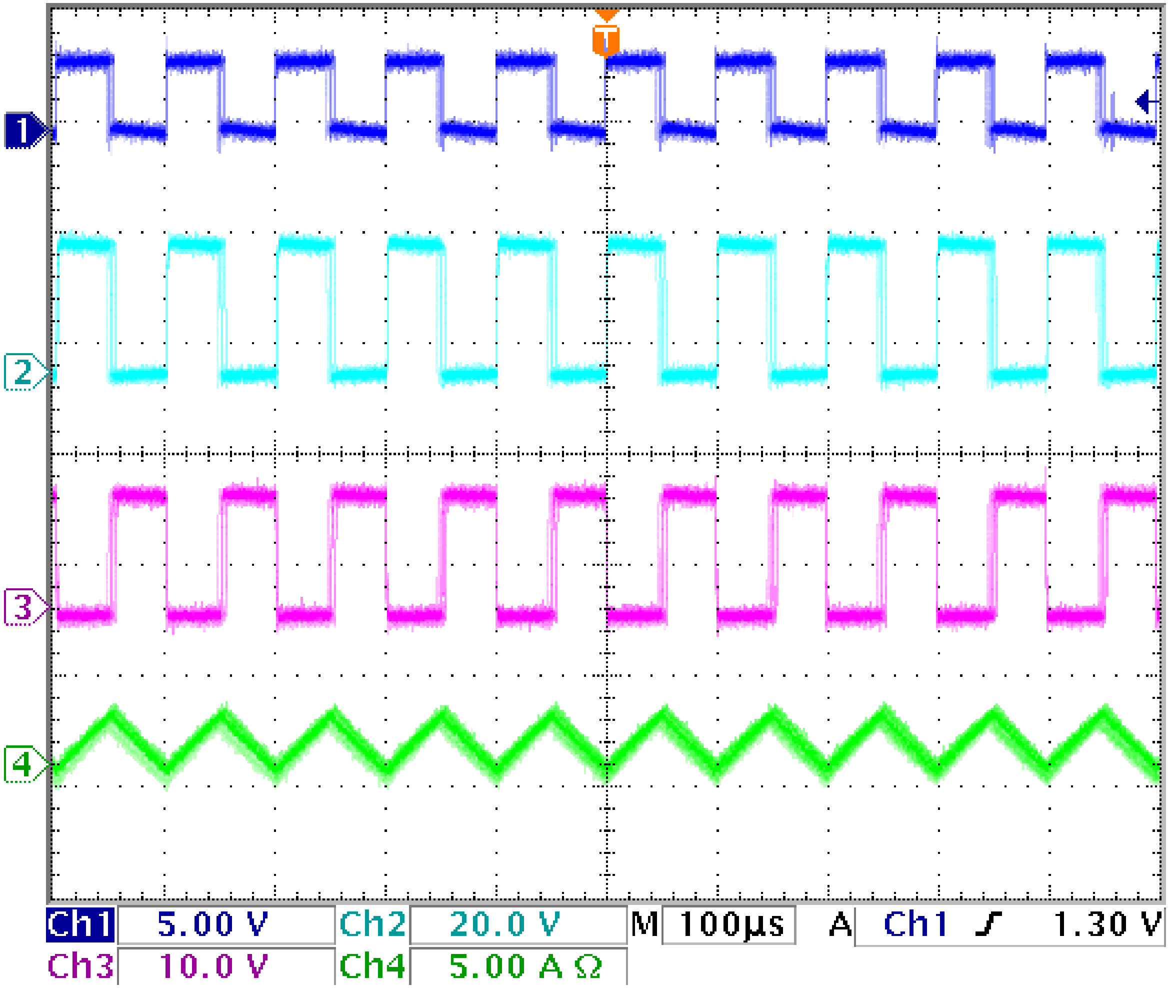


Source: http://ph-elec.com/wp-content/uploads/2012/08/MSP-EXP30G21.jpg

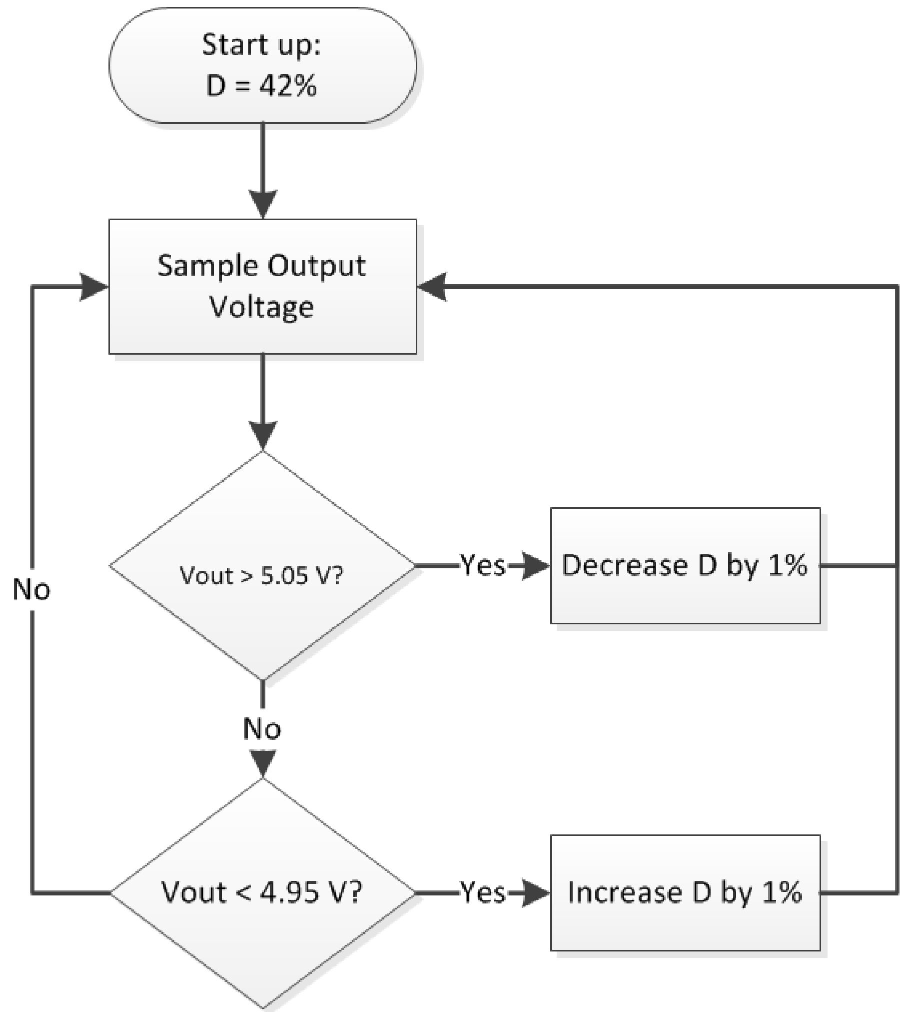
Control Circuitry



PWM Switching Signal



Logic Flowchart



USB Ports 1 and 2

Requirement

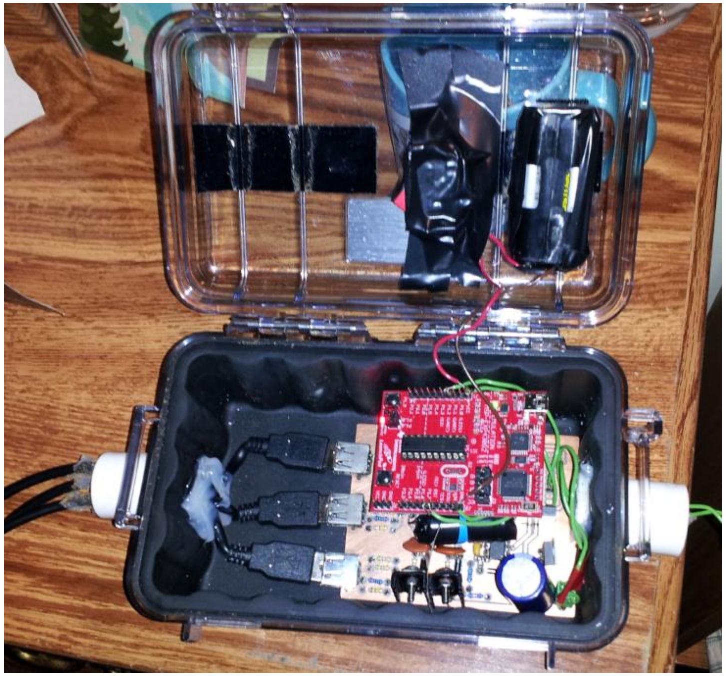
- Referring to the figure, when Pin 1 has a voltage of 4.75 V - 5.25 V, and Pin 4 is connected to GND it is able to successfully charge an iPod and iPad

Pin		Description
1	VBUS	Red
2	D-	White
3	D+	Green
4	GND	Black
Shell	Shield	Drain

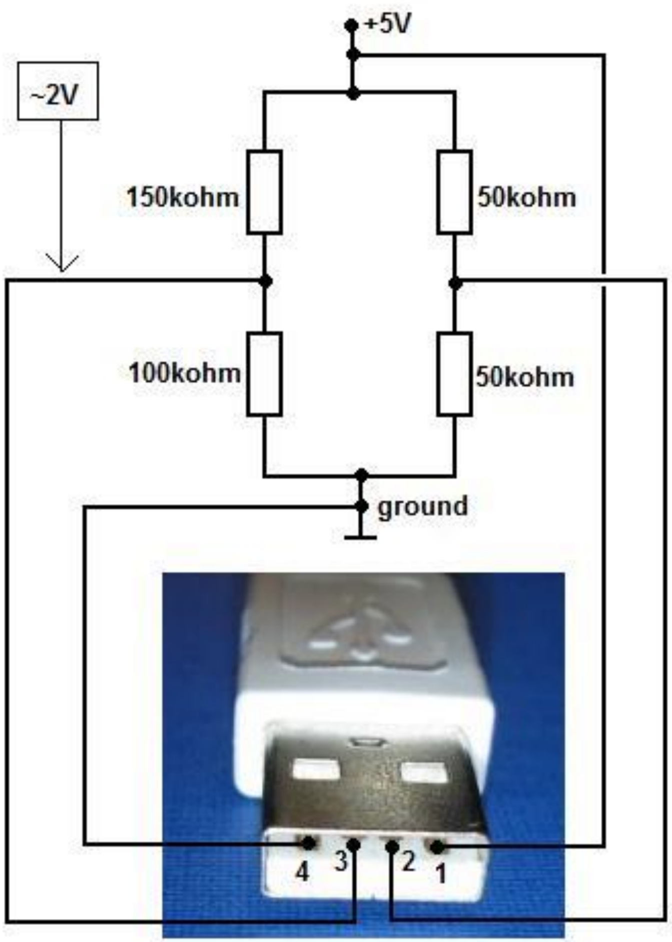
Source: USB.org

Verification

- Implemented USB on the chair and verified that it could charge a USB device



Apple Device Compatibility



Source: pinout.net

- Required for charging
- Non-Apple devices still compatible
- High power charging (10W)

Drink Cooler

Requirement

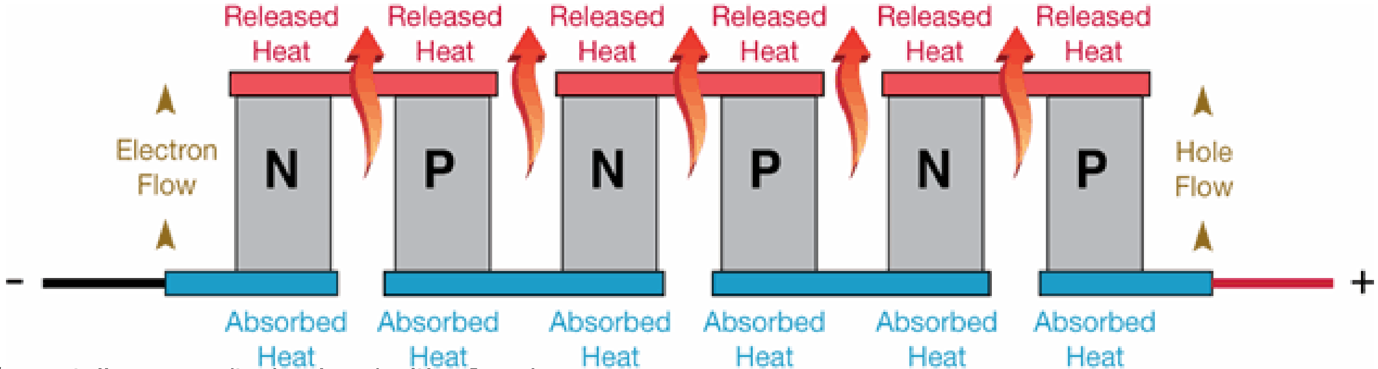
- Keep 12 oz. of water with a starting temperature of 40°-60° F within 5° F of its starting temperature for fifteen minutes when the ambient temperature is 70° F

Verification

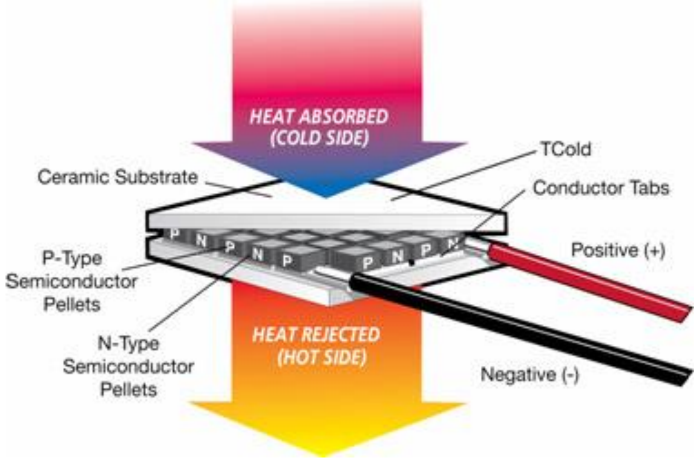
- Use a waterproof digital food thermometer to measure the starting and final temperature of the water to verify that the change in temperature is within 5° F after fifteen minutes

Source: coolitsystems.com

Drink Cooler (The Peltier Effect)



Source: http://www.tellurex.com/technology/peltier-faq.php



- Current flows between two conducting plates through a semiconductor pellet.
- The charge carries transfer the heat from one plate to the other.

Drink Cooler

T_{amb}=74°F		
T_{START} (°F)	T_{15}(°F)	ΔT (°F)
40.1	44.6	4.5
45.0	48.2	3.2
50.9	53.2	2.3
55.0	56.4	1.4
56.4	57.6	1.2
57.6	58.5	0.9
58.5	59.3	0.8
59.9	60.4	0.5

Beach Chair

Requirement

- Can support the weight of the panel, does not exceed 35 lbs, is at rated water resistance and sandproofing of IP62

Verification

- Perform water and sand test to verify that the IP62 rating is achieved. Weigh the chair to confirm its weight does not exceed 35 lbs

Beach Chair

- Mounted Solar Panel
- Mounted Circuit Box
- Mounted Drink Cooler
- Added Backpack Straps
- Final Weight
  - 28.6 lbs.

Source ... rl?sa=i&rct=j&q=&esrc=s&frm

Weatherproofing

- Modified waterproof case while maintaining water and dust resistance.

Source: homedepot.com

Future Work

- Flexible Solar Panel
- Bus USB Configuration
- Built in Speaker and Fan
- Adjustable Canopy
- Improve efficiency through better heat sinks

Source: http://www.powerfilmsolar.com/sitevizenterprise/website/

Wholesale Parts Cost

	Unit Price	Quantity	Cost
Beach Chair	$15.00	1	$15.00
Solar Panel	$41.59	1	$41.59
Waterproof Case	$7.80	1	$7.80
Resistors	$0.04	18	$0.70
Ceramic Capacitor	$0.00	1	$0.00
Metal Film Capacitor	$0.05	2	$0.11
Electrolytic Capacitor	$0.20	5	$1.02
Mosfet	$1.48	2	$2.97
Inductor	$5.65	1	$5.65
USB Connectors	$0.71	3	$2.12
High Side Gate Driver	$1.37	1	$1.37
USB Extention Cord	$1.80	3	$5.39
3.3 V DC/DC	$3.75	1	$3.75
MSP430 Launchpad	$4.30	1	$4.30
MSP430 Chip	$0.25	1	$0.25
Diode	$0.08	3	$0.25
Lowside Gate Driver	$0.55	1	$0.55
PCB	$0.10	12	$1.16
Total:			$93.97

Based on 1000 Chairs

- Total Cost of Materials: $93.97
- Labor/Chair: $30.00
- Overhead/Chair: $30.00
- Total: $153.97
- Customers willing to pay $150.00
- Profitability reached selling 1000 chairs per year

Questions?


ALMA MATER
TO THY HAPPY CHILDREN
OF THE FUTURE
THOSE OF THE PAST
SEND GREETINGS

Special Thanks

Professor Carney

Ryan Corey

Machine Shop

Electronic Parts Shop

Kevin Colvary

Roy Bell