Abstract
This Project is an attempt for improving the communication in rural areas by developing an off-grid portable cellphone backup charger which uses various forms of renewable energy.
The various forms of energy used in this project are solar, wind and heat due to their availability and cleanliness. With the advancements in power, now it is able to harvest energy from sources which are impossible to harvest using traditional energy conversion methods. In this project, a proposed converter for the cell-phone charger was designed, constructed, and then tested. Results show the functionality of the proposed converter to charge Cell-phones. Further improvement of design will also be described.
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1. Introduction:

Cell-phones and laptops are becoming an integral part of our social life. For everything from playing games to cooking food, sending sms messages to attending business conferences, watching movies to doing banking, we depend on our cell phones. Cell-phones and laptops are to becoming a must moving from being a luxury. According to "The Guardian" there are 4.1 billion users of cell phones in the world, which is 60% of the world's population, proving cell phones are becoming the most important personal communication device [1]. Just like how the cell phone is becoming an important need, it is equally important to be able to power up cell phones. According to the International Energy Agency, in 2011, 1.4 billion people around the world did not have access to electricity [2]. There is a huge portion of world population who cannot use a cell phone due to the lack of electricity. Also during natural disasters, like tsunamis or earthquakes, power outages will happen for days. During these power outages, communication is very essential, but the main communication device, cell phones, will be useless due to the lack of power.
This senior project is developing a cell phone charger that uses multiple renewable sources of energy to provide uninterrupted power for cell phones. With further investigation, the most convenient sources that could be used in this project are solar, wind and thermal sources. During the day time, the cell phone charger could use solar energy from the sun. During night time, the cell phone charger could use the heat from fire, or even excess radiating heat from cooking stoves or heaters. The wind source can be used when the consumer is travelling such as by boat. By integrating three different sources, this cell phone charger will be able to provide power to a cell phone in three different diverse conditions
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2. Design Requirements

A. Project Goals:

The project goal is to design a portable cell phone power backup/charging unit that uses three renewable sources of energy, and can be used in rural areas or disaster affected areas

The advantages of this solar panel module is that it is weather proof, strong, tempered glass protected(If it breaks, it will shatter without leaving sharp edges so safe for the customers) and thermal electric insulated coating on rear side. The electrical properties of the solar panel is shown in table 1
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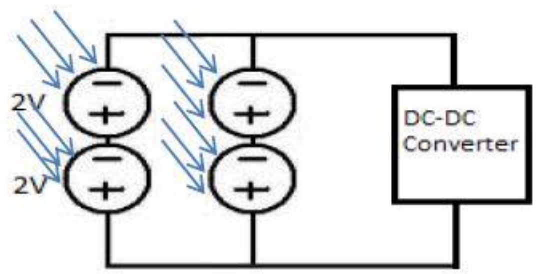
Table 3-1 Properties of solar panel

To attain voltages more than minimum input voltage of DC-DC converter (.9V) even during shades, two solar panels were connected in series as shown in figure 3-2. To reduce the charging time, the current has to be increased. So in order to increase the total current two units of two solar panels (connected in series) connected in parallel as shown in figure 3-2.

Figure 3-2 Solar panel Connections

Material used High density crystalline solar cells
Voltage(OC) 2 V
Current(Isc) 400mA
Power .8W



DC generator

To utilize the wind energy, a DC generator has to be used. The most common DC generator convenient is the computer fan because of its availability, price and light weight. For this project PANFLO FA08T is been utilized.

Two fans are connected in series which is then connected in parallel with the two other fans connected in series. This setup will allow to increase the voltage and current by two times than the rated voltage of single fan. The output of DC generator is then connected to the DCDC converter and it is connected to a battery pack.

Peltier Cell

Another source of energy used in this senior project is the excess heat emitted to the surrounding from cooking and thermal emitting devices. To utilize this heat, a Peltier cell is used. Most common application of peltier cells is for cooling purposes such as wine cooler. If you apply a temperature difference across the plates of a peltier cell, it produces Seebeck voltage due to seebeck effect.

Figure 3-3 Basic structure of Peltier cells

Table 3-2 Perfomance Specifications of TEC1-12706

To create a constant heat source the hot side of TEG is attached to oil filled Altoids container, in which oil absorbs and retain the heat for longer time. The colder side of the Peltier is connected to a heat sink to dessipate heat to the surrounding so that way the colder side will
16
Remain
cold and a temperature difference will be maintained. In this senior project the Peltier cell used is TEC1-12706. The performance specifications for cooling of the TEC1-12706 is shown in table 3-2

without electricity from the grid.
Charger Specifications:
Below is a list of project specifications.

- Should be able charge cell phone without using electricity from the grid
- should be portable
- Should use renewable, readily available energy
- Should be safe to use
- Weather proof
- Affordable in third world countries

Solution Statement
As a requirement, in the project, three renewable sources of energy is included - solar, wind and heat as power sources. The main advantage of having these three as sources is that it is readily available, free of cost and little maintenance. After considering various options and components of design, the design shown in figure 2.1 is selected to implement.

As per the requirement to use three renewable sources, the sources selected were solar, thermal and wind, since they are most readily available. For converting solar power to electrical power, solar panels were used. For converting wind power to electrical power, DC brushless generators are used. For the conversion of heat to electrical energy, peltier cells are used in this project.
Since there are three sources are present in the project, three DC-DC converters are needed to implement this project. For solar input source, a less expensive DC-DC converter is used because of solar panels relatively stable and high current supply. For wind and thermal inputs more expensive DC-DC converter like Ultralow Voltage Step-Up Converter and Power Manager (LT3108)
For Petlier cells, to keep a constant temperature difference a sealed oil (which stores
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heat energy even though the source of energy is removed) container on one side keep it hot and heat sink on other side to make it cool. It is achieved due to the property of oil to restrain the heat provided to it.

Output
Due to the variable availability of solar, low power supply wind and heat power, it is convenient to store the energy into a battery pack and then charge the cell phones from that battery pack. Having a battery pack will also provide an extra layer of back up during emergencies.
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B.Project Timeline:
The following table displays various goals that should be achieved during each week of the winter and spring quarters of 2012. 3. Design

A. Input
As per the requirement input sources of this project has to be renewable, available in rural areas and cheap. So three renewable energy sources: Solar for day time, Thermal for night time, and wind during traveling time is used in this project

Solar Cells
The main considerations given in picking solar cells in this project is durability, strength, output power and customer safety. Considering those as requirements and price, Solmaxx 2V solar panels are selected.

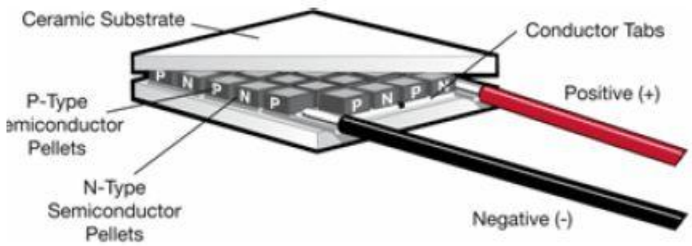

Figure 3-3 Basic structure of Peltier cells

Table 3-2 Perfomance Specifications of TEC1-12706

Performance Specifications

Hot Side Temperature (° C)	25° C	50° C
Qmax (Watts)	50	57
Delta Tmax (° C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

4. Test results
For testing the equipment, each module of the charger is tested separately and analyzed.

Solar Module
The average of various charging test runs of solar mode is displayed in table 4-1

Table 4-1 Solar panel Output
Panel Output
Vout 4.5-4V
Iout .9A-.775A
Boost converter Output
Vout 5.05V
Iout .7A-.6A
Time to charge Backup Battery
Time 3.75-4.5hr
Time to charge Cellphone
Time 1.5 - 2.5 hr
The runs varied from bright sunny day to cloudy day. The output voltage of solar panels were varying from 4.5 – 4 V depending on the amount of sunlight it receives. According to the test results the equipment can be operated at various weather conditions and also able to charge
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the backup battery in around 4 to 5 hours. From the energy acquired in 4 to 5 hours, it is able to charge up to two cell-phones.

Wind Module
Wind module is tested by holding it outside of a moving vehicle. Around 65 mph the module is producing a voltage around 3.5V and current around 110 mA. This current is not sufficient enough to charge a cellphone directly, but can be used for energy harvesting for back-up system.

Peltier Module
The energy acquired from peltier module was really varying because of the difficulty in maintaining a constant temperature difference. For a temperature difference of 25 degree Celsius, the Seebeck voltage starts around 3V and reduces to rapidly diminishes due to rapid heating of heat sinks. With a more advanced cooling system, peltier technology is definitely a path for green energy

Final assembly
The one of the main challenge faced in this project is to design a final product which incorporates all these input modules, converters, and storage and still light and portable. To reduce the size, during primary design to have a multilevel hinged solar panel system was planned. Due to the difficulties in drilling hinge holes in tempered glass of solar panels, it has to change into a static solar panel structure. The picture of final product is shown in figure 4-1. The top part have solar panels and the input selector switch. Under the solar panel all the circuit components and battery pack were securely stored. Below it, the four fans for wind module is securely fixed using wooden brackets
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Figure 4-1 Final Product

Figure 3-

B. Converters

DC-DC converter (for Solar and wind Module)

The DC- DC converter used in this project is a simple Boost converter available in the market. The picture of one used in this senior project is displayed below. The main advantages of this boost converter are its compact size and prize. The specifications of the boost converter are shown in the table 3-3. The output voltage of solar panel set-up displayed in figure 3-2 is 4.75 to 4 V which falls under the input range of this converter, which also has required current rating. The 5V output is the required voltage to charge the battery pack, which makes this converter preferable than others available now. The compact size of this is another reason to select this prefer to LT3652 from linear technology.

Figure 3-4 Boost Converter

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Dimensions 33mm*18.8mm*11mm
Input Voltage 0.9V-6V
Output 3.3V-9V adjustable
Output Current 1A
Conversion efficiency Upto 94%
Output Ripple 50mV
Load regulation ±1%
Voltage regulaton ±.5%

Table 3-3 Specification of boost converter

DC-DC Converter (Peltier Module)

For wind and Peltier input sources, due to very small output power, more complex DC-DC converter has to be used. In this project, the DC-DC converter used for peltier module is *Ultralow Voltage Step-Up Converter and Power Manager* (LTC3108)[5]. The main advantage of LTC3108 is its ability to operate in ultra-low voltages. Figure 3-5 shows the schematic of the DC-DC converter

Figure 3-5 Ultralow Voltage Step-Up Converter and Power Manager (LTC3108)

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Table 3-4 lists the specifications of the LTC3108 DC-DC converter. Due to its ultra-low input voltage range, LTC 3108 is one of the best DC-DC converters available in the market for a Peltier cell. The wide range of input voltage (20mV to 400mV) makes this suitable for a unstable low voltage input like Peltier

Table 3-4 Operating parameters of LTC3108

C. Output

3 way switch

All the outputs from the DC-DC converter go to a source selector shown in figure 3-6. Source selector allows you to manually select which source to use in order to charge the battery pack/Cellphone.

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Figure 3-6 Circuit diagram of the source selector

Battery pack

The battery back used in this senior project is a standard Li-Poly (2800mAh) battery. The main advantage of using 2800mAH battery is during the day time unit can charge for a longer time and store more energy in the battery and during the times when power is not available, the store energy can be used to charge up to two cellphones due to its high storage capability

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The final product is 18cm(width) X 18 cm (depth) x 12 cm height excluding the solar panel extension. It weighs 744 grams. If it is commercially manufactured, by making tempered glass solar panels, using custom designed plastic fabrications, the size of the product can be reduced significantly.

The solar panel module of this product works perfectly fine and the design could be used to commercially produce the product. The Peltier module needs a design improvement to have a better heat sink. Another improvement that could be suggested is to use different type of a DC fan which can output more current, that way it will reduce the charging time

Table 4-1 Solar panel Output

Panel Output		
	Vout	4.5-4V
	Iout	.9A-.775A
Boost converter Output		
	Vout	5.05V
	Iout	.7A-.6A
Time to charge Backup Battery		
	Time	3.75-4.5hr
Time to charge Cellphone		
	Time	1.5 - 2.5 hr

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5. Conclusion

Working on this project helped me to go through the various steps of a project, such as brainstorming, designing, planning and executing. It has also taught me a lesson that various things might go differently from the original plan due to various reasons

5. Conclusion

Working on this project helped me to go through the various steps of a project, such as brainstorming, designing, planning and executing. It has also taught me a lesson that various things might go differently from the original plan due to various reasons, and as an engineer you should expect it all the time. I was also able to use the concepts of power electronics I learned in class in this project.

The resulting design of the module can be built and marketed in less than 50 dollars in rural areas. It is a good working charger powerful enough to harvest the sun power and store energy required to charge up to 2 cellphones. This product would be a good starting step in developing the communication systems in rural areas.

Even though wind and peltier module need further improvement as explained in the previous chapter, with the developments in the field of science and technology, we are not that far to have an improved DC generator powerful enough to charge a cellphone, or to have a cooling system fast enough to reduce the temperature of the cold side of peltier. Overall, this project meets the goal of providing a cell-phone charger for rural areas though the use of renewable energy.

DC-DC converter

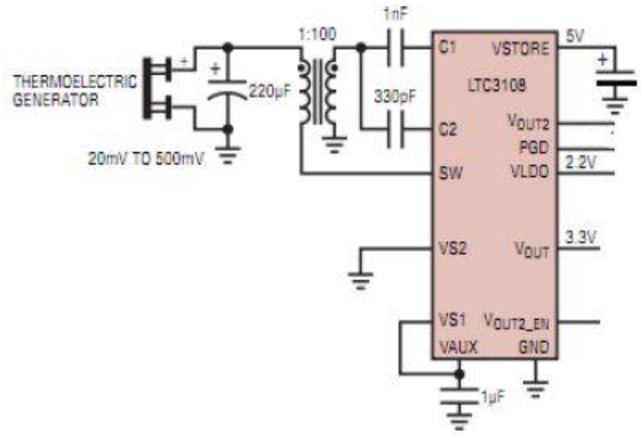
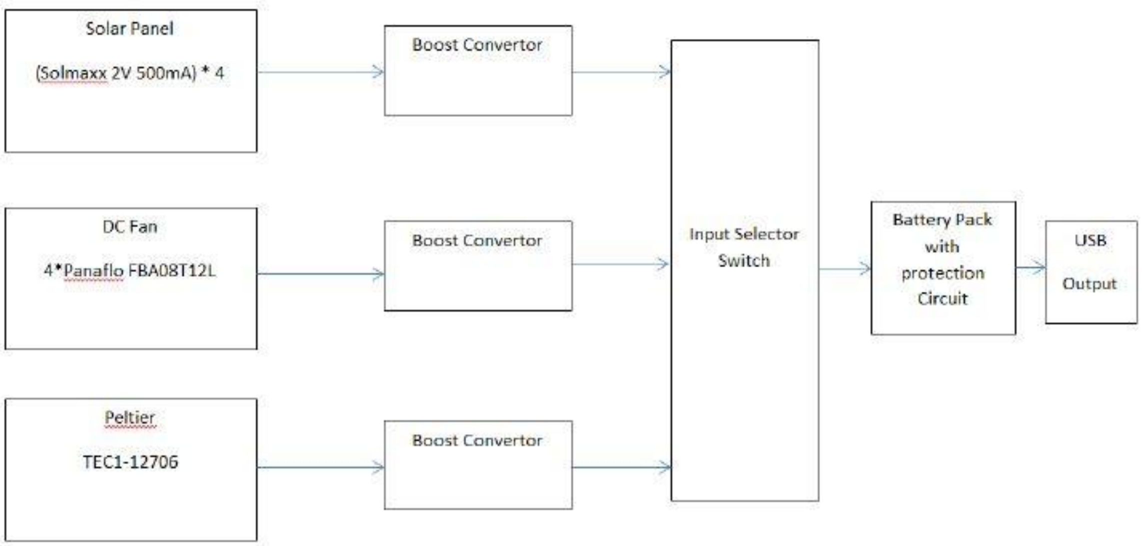
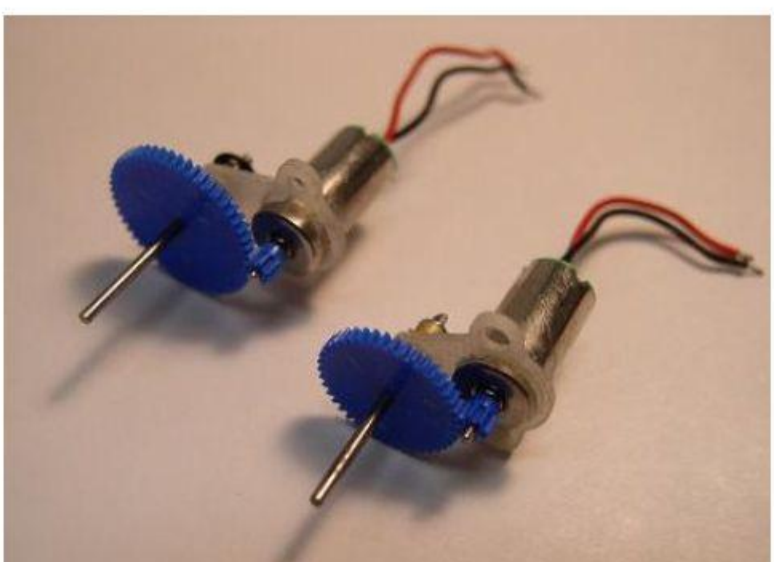


Figure 3-5 Ultralow Voltage Step-Up Converter and Power Manager (LTC3108)



Falcon Models PU03 & PU04 Pager-Motor Propulsion Sets

By Gordon Johnson



Bike that charges your cell phone as you ride! by flaresam

5 Steps

Step 3: Mounting the Gear and Motor onto the bike

Additional info for below:
http://www.bostonmicronauts.org/gj-articles/Falcon-PU03-04.pdf

Falcon PU03/04 with Didel 4.5 Ohm Pager at 3.6 Volts

	Predicted Motor Measures: Amps	Efficiency (%)	Power (W)	Motor Rpm
MAX EFFICIENCY	0.23	52.4	0.50	32,818
MAX POWER	0.41	43.4	0.64	23,519

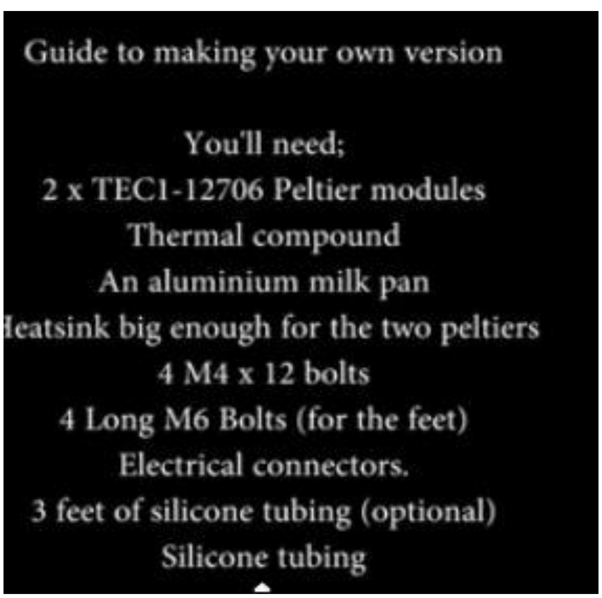
Prop & Gearing: Prop	P/D	Prop Wt	Static Measurements: Amps	Watts	Thrust (g)	Prop Rpm	Motor Rpm
PU04, 6.5:1 Gearing							
GWS 4x4	1.00	1.07	0.37	1.33	9.8	4,200	27,300
KP00 96mm, 3.7x2.8	0.76	1.00	0.35	1.26	9.9	4,320	28,080
Gasparin 4x3 wide	0.75	0.40	0.26	0.94	10.2	5,130	33,345
GWS 4.5x4	0.89	1.35	0.39	1.40	11.4	3,750	24,375
Gasparin MCF 5x3 wide	0.60	0.53	0.40	1.44	12.5	3,510	22,815
Gasparin MCF 5x3 narrow	0.60	0.49	0.37	1.33	13.2	3,930	25,545
GWS 5x3	0.60	1.44	0.36	1.30	14.0	3,960	25,740
GWS 5x4.3	0.86	1.56	0.41	1.48	14.1	3,420	22,230
Westechnik 4.8x3.1	0.66	0.51	0.40	1.44	14.0	3,720	24,180
PU03, 5.25:1 Gearing							
U80 3.2x2.0	0.63	0.68	0.27	0.97	7.8	6,870	36,068
Gasparin MCF 4x3 narrow	0.75	0.37	0.36	1.30	9.8	5,490	28,823
Gasparin MCF 4x3 wide	0.75	0.40	0.37	1.33	10.5	5,220	27,405

* MCF prop weights include my plasic prop hubs.

Peltziers:

Take 2 minutes to warm up. A 1 to 3 vdc motor will turn a fan when enough are wired in series.

Excellent Video on Peltizer making with drilling etc.
http://www.instructables.com/id/Thermoelectric-USB-charger/



video Thermoelectric Fan Powered by a Candle

A Thermoelectric generator powered by a tealight. It started as an experiment of how much power I could get from one candle. But I liked the idea and it worked really well so I built this electric-mechanical ornament. I did not use a high temperature TEG-module, but instead a cheap TEC-module. That can still handle 200 degrees Celsius which is good enough.

Please see my other project with a more powerful TEG:
http://www.instructables.com/id/Battery-Charger-Powered-by-Fire/

Concept:
It is also called a peltier element and when you use it as a generator it's called seebeck effect. You have one hot side and one cold. The module generates power to drive a motor and the motor fan/air flow will cool the upper heat sink. Higher temperature difference => increased output power => increased motor RPM => increased air flow => increased temperature difference and so on. The airflow will spread the heat into your room, which is the purpose of this construction.
http://en.wikipedia.org/wiki/Thermoelectric_effect

If you unmounts the basement you could also use it as a stove-fan or move air from other heat sources. The motor start to turn at about 15 degrees difference, which to my surprise worked when I just went outdoors with it and the upper heat sink got cooler than the basement. You can place it in hot water, on an ice cube, a pizza and it works just as fine.

Total cost was about 50€ (incl. shipping costs). I used some spare parts but I bought most of it.

Components used:
- **CPU-cooler (cold side): Zalman CNPS5X (Base plate: 33x33mm)**
- **CPU-cooler (hot side): From an old PC (WxLxH=78x63x67mm)**
- **TEC-module: TEC1-07110T200 (30x30x3.3mm)**
- **DC Motor: 1,5-3V**
- **USB-fan (metal, only needed the fan)**
- **Thermal paste: Arctic MX-4**
- **A piece of wood**
- **Two pull springs**
- **Four M4 bolts and two M3 bolts**
- **Aluminum tubes (optional)**

TEC specification (at ΔT=68C):
Vmax: 8.5
Imax: 10
Qmax: 52.7
Tmax: 200 degrees Celsius
Source: http://www.termo-gen.com

Construction:
First of all, it does not need to be exactly those components. Other heat sinks, TEC/TEG, motor, fan, thermal paste, bolts and base plate can be used. Main concept rules are: • A TEC or TEG module (smaller dimension than upper heat sink base plate). Specifications are not that important but make sure it can handle high temperature. Many modules are only 100 degrees C and then you need to modify the construction as it gets warmer than that.
- **One hot side that is not hotter than TEC max-temp (My candle flame never touches the surface)**
- **One cold side, an efficient heat sink (heat pipes) are a good choice**
- **Good thermal paste to maximize temperature difference**
- **Low voltage motor, around 1V. I prefer it to be quite (low dB)**
- **Fan with high air flow at low RPM**
- **Base plate that adds stability, holder for light, isolate heat**
-

The lower heat sink (hot side) was cut and polished to get it nice looking. I kept 5mm of the fins to absorb the heat well when the light flame burns and increases distance to the surface. New dimensions are 78x63x15mm. 4 holes are drilled through the heat sink and threaded as M4. 4 bolts will hold the lower heat sink on top of a wooden platform. Bolts go through the platform from below, covered with aluminum pipes for a better looking design and are screwed into the heat sink. The distance between wood and heat sink is 35mm but I would make it 40-45mm as the flame almost touches the surface. You don´t want that because it creates black soot. The lower heat sink gets really warm but at the same time it works as a cooler to not get TOO warm, that would melt the TEG-module.

Two springs attached to M3 bolts fixate the upper heat sink on the lower, with TEC-module and thermal paste in between. Both surfaces of the TEC are covered with a thin smooth layer of thermal paste. The springs adds pressure as well as isolate the heat to travel to the cold side. The upper heat sink could also be screwed into the lower heat sink but then you need isolated screws.

The TEC is directly attached/soldered to the motor and the motor is attached to the upper heat sink by another small piece of metal and a cable tie. The fan is attached to the motor with a small belt wheel and glue.

Result:
I think the hot aluminum part get to about 100-150 Celsius, I measured the temp with a grill thermometer covered in thermal paste but can´t tell how accurate it was. I measured 0.4V and 0.25A with one candle and 0.67V and 0.54A with two. That results in 0.1W resp. 0.36W output power. The efficiency to produce electricity this way is not that impressive though. A candle produce about 25 Watts, that means 0.7% efficiency.. But who cares, everything this machine does will eventually end up in heat any way =) That is a bit interesting, you increase the room-heating speed (I think) but looses nothing..

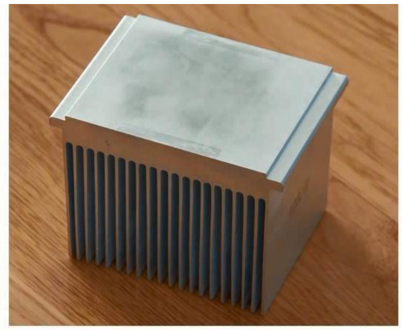
It is a bit noisy to have running all the time. To find the optimal motor/fan => airflow/noise level will require some more experimenting.

Mod Proposals: • Skip the base platform and bolts and use it as a stove-fan.
- **Use two/four TECs side-by-side to multiply output power. Add a 5-10mm thick copper plate that covers all modules and then place the CPU-cooler on top of that.**
- **Use a brushless DC motor and a suitable fan to make it noiseless.**
- **Build in a slow motor beneath the platform to make the whole thing spin 360 degrees.**
- **Put wheels on the platform.**

Edit:
I have changed the motor to a "Tamiya 76005 Solar Motor 02 (Mabuchi RF-500TB)". Got it on Ebay. It´s incredibly strong at low RPM and I give it only 0.5V. A very good motor, but best of all, it´s quiet! I cannot hear it at 2m distance at full speed. It also gives stronger air flow. Now I can run it all time =)

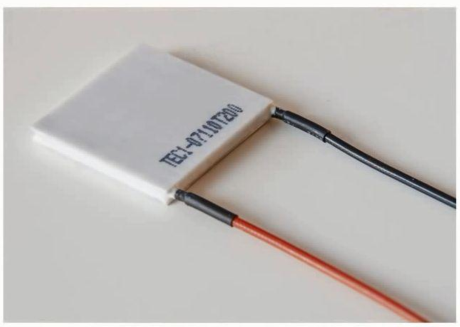
Images from above on following pages:

CPU cooler: Zalman CNPS5X



CPU cooler 2: From old PC

USB Fan (fan blades)



TEC-module: TEC1-07110T200

Peltier units transform the difference of heat to electricity. They belong to a class of materials called "thermoelectrics" and are one of auto industry's greatest hopes in what regards the savings obtained from an internal combustion engine.

With a Peltier unit, a car can effectively decrease its fuel consumption by recovering part of the energy the engine loses as heat and transferring it to a battery, thus helping power the car electronics and even air conditioning. In the case of hybrid cars, a Peltier unit could also translate heat into motion.

Here's how you can develop your own Peltier energy-producing device at home:

1. take two radiators big enough for your needs and wet them with thermal fan paste on the place where the Peltier unit will get stuck(you can find it in any IT store/RadioShack).

2. fabricate a thermal insulator to separate the two radiators. It can be from anything you can think of as long as it fits for your application's maximum temperature (doesn't melt). The insulator should not be thicker than the Peltier unit you'll put between the radiators. Cut an opening of the size and shape of the Peltier unit so it fits perfectly inside the insulator. Also make space for the two wires.

3. Screw the whole assembly together (the two radiators, the insulator with the Peltier unit) and apply a heat source on one of the radiators. The longer you wait, the higher the voltage and current (power) you get from the Peltier device.

Of course, everything has its limitations, but with a unit the size of the one in the following video, you'll easily be able to power small gadgets you have around your home. A bigger unit would serve higher purposes.

Misc Data:

Use a peltizer module to turn a motor, powered by a candle, than the motor turns a stepper motor charging a battery.

The lowest amp batteries are pager motors, which have okay torque and run off cell phone batteries.

2800mAh Batteries used in drills and motors -

UPDATE: Swapping batteries in mine with LG Chem Li-Ion 18650 Cylindrical 3.7V 2800mAh has made these things amazing. The stock battery is 1300mah, so the speed and power feels like double with the upgraded battery. It holds a charge a lot longer, too. (these seem to die too quickly)

As researched earlier, remote control car batteries are best for high capacity charging. 2800mah is used in some remote control car kits.

Suppliers of these packs include:

2800mAh Rechargeable Li-ion Battery Pack for Wii Fit - 4.8 volts . This pack can also be charged through USB cable.

http://www.topbuy.com.au/2800mah-rechargeable-li-ion-battery-pack-for-wii-fit-p77116.html?utm_source=topbuyMYS&utm_medium=48&utm_campaign=TBLC-XX3000243&utm_content=1498

Wild Scorpion 11.1V 2800mAh 30C Li-Poly Battery

http://www.banggood.com/Wild-Scorpion-11_1V-2800mAh-30C-Li-Poly-Battery-p-85578.html?currency=USD&utm_source=google&utm_medium=shopping&utm_content=miko_ruby&utm_campaign=RC-Hlicopter-us&gclid=CJvUt9vj5b0CFUNhfgodlq0Arw

11.1V 30C 2800mAh Li-poly Battery for RC Model
http://absolutelymedia.com/store/remote-control-toys/11-1v-30c-2800mah-li-poly-battery-for-rc-model-3360002087969906/

Powerocks is the best source for backup portable power on-the-go. Its 2800mAh battery capacity, gives you enough juice to fully charge most smartphones two times. Magicstick includes a Micro USB to USB connection cable for easy charging/recharging and a soft drawstring carrying bag.

I have done a little research and it appears that the TEC modules have an upper end of about 180 degrees C. However, I though that if you used some Thermo-trex 2800 wire (resists up to 600 deg. C continuous heat) and a good enough heat sink, you could have a power generation module that you could suspend over a cooking fire or mount in a chimney type arrangment

Getting back to the possible power output. I figure that to be most useful, I'll need to use 4 Peltiers - 2 pairs wired in parallel, which are then wired in series. From earlier experiments, I could probably get 8V and 400mA. With a little voltage regulation, it should easily be enough to power a device from a USB plug. Plus, with the 8V maximum, the fan will get up to its maximum speed fairly quickly.

The output voltage will vary with input heat, please use a DC-DC converter or transistor to stabilize its output voltage

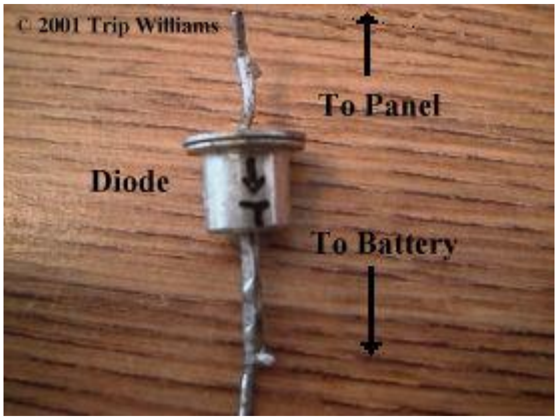
With recent advancements in thermoelectric material performance, thermoelectric generators have become a viable alternative for power generation using small temperature differentials with benefits that can not be found in other energy conversion methods. The power generated by a thermoelectric generator, using a small ΔT, is characterized by a relatively high current (-~5 A), but a relatively low voltage (<0.3 V), which is often not suited for many practical applications. In order to make use of the thermoelectric generated power in applications requiring a higher voltage, a DC-DC step up converter that can handle low input voltage is needed. Commercial available DC step up converters require an input voltage of at least 0.7 volts, which is the minimal voltage required for operating a bipolar junction switch. Several novel approaches for low input voltage DC-DC converter concepts have been studied and proved to be feasible. Their operations are based on some unconventional methods achieving DC to AC conversion for low input voltage. In one solid state approach, a normally-on transistor and a tunnel diode were utilized to achieve low voltage oscillation.

Candle Lights can burn up to 6 hours:
Northern Lights Candles 50-pc. 6 Hour Long-Burning Tealights
by Northern Lights Candles

Battery Charging

Battery Charging:

If you plan to charge your batteries directly, you'll also need some battery leads for the solar panels, and of course you want a fuse in there! So while the soldering iron is hot, we might as well do all this at once...



(Notice the markings on the diode)

Your diode will have a stripe at one end. About all you need to remember is that current/electricity flows TOWARD the stripe end. Solder the diode to your solar panel's positive wire with the stripe on the diode furthest from the panel. The stripe end should be toward the battery.. this is important! After adding the diode to the wire from your solar panel, solder your positive battery lead (with fuse holder) to the stripe end of the diode... then solder the two negative wires together (nothing goes in between them).

Charging Batteries

There are SEVERAL good articles here in the Rubicon and Alpha site about charging batteries, but charging straight from solar panels is just a bit different, especially when you start getting into higher wattage/amperage/voltage panels. You can easily cook your batteries if you aren't careful... Yeah, with the smaller panels (5 watts, 12 volts, or so) you can basically hook em up to the battery and forget it.. there is not enough current to cook off a big 12 volt deep cycle battery. The little panels won't hurt your batteries, but they also take a LONG time to charge your batteries.

As you can see, one 21 watt solar panel can fully charge a big battery pretty quickly. Normally for a solar cell of this size, we'd use a charge controller to keep the voltages from going up so high (as was the case with the small 12 volt gel cell), but I wanted to make a point about how much voltage these solar cells can put out in full sunlight, and how quickly you could ruin a battery if you aren't careful... leaving that gel cell charging at 16+ volts for even a few minutes after it's "peaked" could cook it, and since it's sealed... BOOM! However, there's not a lot of risk charging a big deep cycle battery with one 21 watt cell, it could probably sit there all day and take it. Could it sit there and take current from two solar cells all day? Probably not, which is why we'd use a charge controller