Solar Powered LED Lantern for Developing Countries

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Abstract

In recent years, both LED and solar technology have become the focus of sustainable energy. LED lighting uses significantly less power than its fluorescent competitor. Solar cells enable clean, natural, and portable power. As these two entities become more efficient at exponential rates, the hope for the wide use of off-grid lighting in less developed countries seemingly increases at the same rate. Currently, there has been a development of industry for portable solar powered lighting systems. Before designing a product, a study was conducted of current products on the market that aim to light dark homes. This study and design of the solar powered LED lamp system takes into account many factors including quality, affordability, size, and functionality. After producing a final product, it is apparent the current issue that remains is cost. However, in the near future, research and projections prove the world will surely see the cost of LED and solar technologies decrease substantially.

Acknowledgments

Dr. Samuel Agbo
Thank you for all your help with this project. Prior to this year, I had little knowledge of the energy crisis in Africa. Now it is an issue that I have gained much interest in and hope to be more involved with in the near future.

My Family
Thank you for all your support of the years and always believing in me.

Introduction/Background

Technologically advanced countries have broken ground on new developments of sustainable energies. With the relatively high amounts of resources and funding available, the sky is the limit. In the United States, most of these new sustainable technologies are affordable to the average consumer. On the other end, too many third world countries suffer from the lack of reliable energy at all. Kenya, for example, has a grid only in select regions of the country. Even then, the power distribution is nowhere near as sophisticated as in America.

Figure 1: Kenya overhead power lines

The dominate method of lighting in developing countries, particularly sub-Saharan Africa, is fuel based. Over the years, research has suggested that various fuel-based lamps can not only be inefficient, but also a dangerous health hazard. The most widely type of fuel used is kerosene, for no reason other than its availability. This expensive, fast-burning, low lumen output fuel is believed to heavily contribute to the hazardous living conditions in poor countries. When resources are scarce and education of modern technologies lack, the people have no choice but to make do.

Figure 2: Two types of Kerosene lanterns

It is quite apparent that the combination of solar cells, LEDs, and dependable batteries will be the savior of off-grid communities. Environmentally friendly, efficient, low maintenance, and reliable are all characteristics that fuel-based lighting lacks. Imagine, outside of every home lies a solar panel charging a light, long lasting battery in the daytime. At night, that same battery powers an entire LED illuminated room.

As stated earlier, more developed countries are rapidly adapting to the idea of sustainable energy as a necessity. As materials become much more efficient and cheaper to produce, these advanced nations will need to take initiative as world leaders to guide less fortunate countries to a luminous future.

The primary objective of this study and design of the solar LED lamp system is to gain a deeper understanding of the various trade-offs to develop an understanding of a product with long term reliability, efficiency, portability, and most importantly, low cost. With these factors in mind, the design of a product will be implemented with the ultimate aspiration of competing with devices already in the industry.

Requirements and Specifications

The solar powered LED lamp system will have a wide range of uses; however it is primarily targeted to fill the needs of less fortunate persons of developing countries. That said, it is important to consider what exactly they would use the lamp for, and how long.

The "Lighting Africa" initiative serves as the link between private businesses who design green off-grid lighting and communities that desire such products. A video was recently released on the website describing the benefits of LED lighting in Kenya. In short, long lasting illumination throughout the night allows for students to study longer and business owners to operate well past sunset. One individual testified that his new lamp has nearly doubled his income as a bicycle mechanic, all because he can operate his business until midnight rather than 6 pm.

The requirement of the final product design is a well tested LED solar lamp system that can operate at maximum performance for a minimum of nine hours.

Important Units of Measurement

1. Luminous Flux (Lumens) – measurement of light emitted
2. Battery Capacity (Amp-Hours) - the amount of charge available in the fully charged battery.
3. Energy (Watt-hours)- the amount of energy stored in the battery
4. Cut-off Voltage (Volts) – The minimum allowable voltage. It is this voltage that generally defines the "empty" state of the battery
5. Charge Voltage (volts) – The voltage that the battery is charged to when charged to full capacity

Design Procedure

LED Selection

The design of the entire system is centered on the selection of the light source. The LED bulb should provide the highest lumens/watt ratio while also keeping cost to a minimum. This will ensure a high output of light with low power. Consequently, low power will yield a relatively inexpensive and light battery selection. Finally, a low-power battery will require a less demanding solar panel.

Several types of 12V light bulbs were explored in different stores and websites. A few fluorescent and incandescent bulbs were considered, just to show that the LED light source demonstrates the best desired performance by far.

Manufacturer /Product	Type of Light	Rated Life (Hours)	Power Output (Watts)	Luminous Output (Lumens)	Lum/Watt Ratio	Cost ($)
LED Wholesalers MR16	LED	50,000	3.8	196	51.57	12.99
LED Wholesalers MR11	LED	30,000	2.1	140	66.67	8
LED Wholesalers MR16 (Dim)	LED	50,000	9	480	53.33	11.5
LED Wholesalers Type G4	LED	50,000	3.6	288	80	9.95
Osram 499529	Halogen	2,000	50	230	4.6	2.47
Sunmia	LED	50,000	3	210	70	32.99
KolourOne S8813	LED	30,000	4	200	50	26.99
Revolution200	LED	30,000	2.5	200	80	22.47
Geo Bulb	LED	50,000	2	68	34	24.95
Camco 41313	Fluorescent	no data	15	200	13.33	10.26
HELLA H83190001	Incandescent	no data	40	200	5	5.29

Table 1: Various Light Bulbs

The presented data reflects that the LED Wholesalers Type G4 bulb is clearly the best selection amongst its competitors. At only 3.6 W, this device provides 260 lumens at a very reasonable price, and will last for an astounding 50,000 hours.

Battery

The selected LED bulb and desired maximum operating time allows for a calculation of minimum battery capacity.

LED power: 3.6W

Operating Voltage: 12V

Desired Operating Time: 9 hours

$$\text{Capacity} = \frac{LED\ power}{operating\ voltage} \text{ x } desired\ operating\ time$$

Plugging values into this equation:

$$\text{Capacity} = \frac{3.6\ W}{12V}\ x\ 9\ hours = \mathbf{2.7\ ah}$$

This result leads to the search for a **3 amp-hour battery**.

The next obstacle calls for a selection of the type of battery. Various batteries have a wide range of applications. The most important features for this particular application are: life cycle, weight, and cost. The table below shows the features of the most widely used batteries.

NiCd	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Gravimetric Energy Density(Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mΩ	100 to 200 6V pack	200 to 300 6V pack	<100 12V pack	150 to 250 7.2V pack	200 to 300 7.2V pack	200 to 2000 6V pack
Cycle Life (to 80% of initial capacity)	1500	300 to 500	200 to 300	500 to 1000	300 to 500	50 (to 50%)
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	moderate	low	high	very low	low	moderate
Self-discharge / Month (room temperature)	20%	30%	5%	10%	~10%	0.3%
Cell Voltage(nominal)	1.25V	1.25V	2V	3.6V	3.6V	1.5V
Load Current - peak - best result	20C 1C	5C 0.5C or lower	5C 0.2C	>2C 1C or lower	>2C 1C or lower	0.5C 0.2C or lower
Operating Temperature(discharge only)	-40 to 60°C	-20 to 60°C	-20 to 60°C	-20 to 60°C	0 to 60°C	0 to 65°C
Maintenance Requirement	30 to 60 days	60 to 90 days	3 to 6 months	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)
Cost per Cycle(US$)[11]	$0.04	$0.12	$0.10	$0.14	$0.29	$0.10-0.50
Commercial use since	1950	1990	1970	1991	1999	1992

Table 2: Types of batteries and their characteristics

Based on cost, both Lithium-ion and Lithium-ion polymer are eliminated from the selection process despite their remarkably low density. Next, the reusable alkaline battery is eliminated for its low life cycle. Nickel Cadmium and Nickel-Metal Hydride require too much maintenance; the number one priority is to provide a long-lasting battery. Since the targeted customer is expected to have little to no technical knowledge of batteries, maintenance should

be kept to a minimum. Also, a high overcharge tolerance can also help sustain battery life and safety.

Despite its flaws, the Lead-Acid battery was selected to be implemented in the lighting system. Light weight may certainly be sacrificed for long life. Perhaps in the near future, the Lithium-Ion batteries will become the choice of all batteries applications the price decreases.

The table below summarizes the specifications that need to be met for the selected battery.

Battery Type	Nominal Voltage	Capacity	Energy
Lead Acid	12V	3 A-h	36 W-h

Table 3: Selected battery specifications

Solar Panel

With the light source and battery selected, it is now appropriate to select the solar panel. Regulated by the charge controller, the solar panel will directly charge the battery, and therefore needs to be compatible to charge the battery in a timely manner.

Solar panels are normally rated based on power and voltage. Quite obviously, the panel will need a 12V rating. The power rating, however, is based on the energy (W-h) rating of the battery, and the amount of desired charge time. For this application, the appropriate charge time is 6 hours. Therefore,

$$P_{panel} = \frac{Battery\ Energy}{charge\ time}$$

$$= \frac{36\ Watt\text{–}hours}{6\ hours}$$

= **6 Watt panel**

The search now begins for a portable, quality, and cost friendly 12V, 6W solar panel.

DC Storage Battery	Solar Panel
1.2V	2V ~ 2.5V
2.4V	3.5V ~ 4V
3.6V	5V ~ 6V
6V	7.5V ~ 9V
12V	15V ~ 18V

Table 4: DC Battery and Solar Panel Matching Guide

One important fact about solar cells the way they are built. Some are monocrystalline, while others are polycrystalline. The monocrystalline cells generally produce the best quality; they are made from a single crystal of silicon. On the other hand, polycrystalline cells are made from multiple crystals. They generally absorb less sunlight and therefore will be larger to match the performance of monocrystalline cells. The upside is that polycrystalline cells are cheaper.

The table below shows the various types of solar cells explored.

Manufacturer	Open Circuit Voltage (V)	Power rating (W)	unit cost	Dimensions (inches)	Material
HQRP	17.5	6	33.95	10x11.57x0.98	mono
Instapark	17.5	5	24.95	11x8.5x0.67	mono
Sunlinq	17.5	6.5	91.99	12 x 8 x 2 (foldable)	mono
Ali Express	17.5	5	32.2	7.28x11.22x0.71	poly
Ali Express 11438	18	5	24.99	11.6x7.68x0.2	poly
wtotoy	18	5	24.99	11.6x7.68x0.3	poly
CINCO	21.3	5	11.86	12.44x9.05x0.87	mono
Power Up BSP-5-12	17	5	29.95	9.75x 9.38 x 1.31	poly
Solartech SPM005P-R	17.1	5	29.95	13.8 x 8.8 x 0.98	poly
Wind and Sun	17	5	32	9.75 x 9.38 x 1.31	poly

Table 5: Various Photovoltaic Sources

Taking all factors into consideration, the Power Up brand was selected. The ideal choice would be a foldable panel, but these products are too expensive. The Power Up panel offers a fairly compact size for a good price. 6 W rated panels are scarce in the industry, so 5W was selected instead. Using 5W as opposed to 6W will increase the charging time from 6 hours to 7.2 hours, a **1.2 hour difference**.

Charge Controller

Simply attaching a solar cell to charge a battery is not practical. The cell can easily overcharge the battery, causing potential hazards. A charge controller must be implemented to regulate the charging of the battery.

The figure below is a schematic of the charge controller to be implemented in the system.

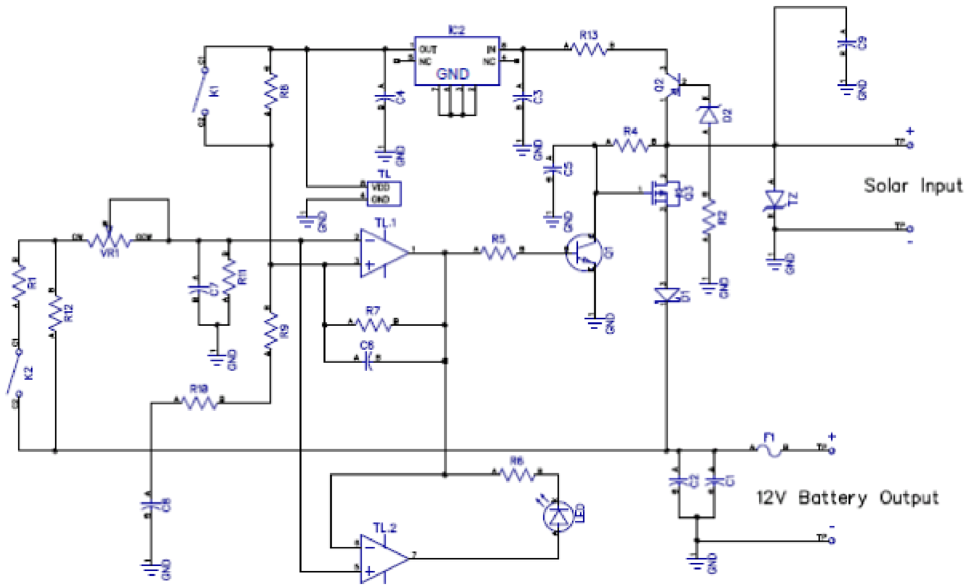

Figure 3: Charge Controller Schematic

The tables below list of the components and their values (if applicable):

Component	Description	Value (Ω)
R1	Resistor	100Ω
R2	Resistor	2.2k
R3	Resistor	N/A (removed)
R4	Resistor	10k
R5	Resistor	100k
R6	Resistor	750
R7	Resistor	4.7M
R8	Resistor	100k
R9	Resistor	200k
R10	Resistor	180k
R11	Resistor	75k
R12	Resistor	300k
R13	Resistor	100
VR1	Potentiometer	100k

Table 6: Design Resistor Values

Component	Description	Value (µF)
C1	Capacitor	47 (50V)
C2	Capacitor	0.1
C3	Capacitor	0.1
C4	Capacitor	0.1
C5	Capacitor	0.01
C6	Capacitor	0.01
C7	Capacitor	0.1
C8	Capacitor	0.1
C9	Capacitor	0.1

Table 7: Design Capacitor Values

Component	Description	Part #	Remarks
IC1	OP Amp	TLC2272CP	
IC2	Voltage Regulator	78L05	
D1	Diode	19TQ015	
D2	Diode	1N5242	500mW zener diode
Q1	BJT	2N3904	NPN
Q2	BJT	2N3906	PNP
Q3	Power MOSFET	IRFR5505	55V P-Channel
LED	Light emitting diode	4301F1/5-A	red/green
TZ	TV diode	PESD12VS1UJ,115	27V

Table 8: Miscellaneous Components

The heart of the charge controller lies in the TLC2272CP. This dual op-amp is used as two comparators. The regulated voltage of the panel is input into the positive terminal, and the desired battery voltage is input into the negative terminal. The desired battery voltage is set with VR1, the 100kΩ potentiometer. The voltage ranges from 12-13V. The panel will continue to charge the battery as long as the $+in_1$ is greater than the $-in_1$. The output will provide a "high" voltage and be input into $+in_2$. As long as this voltage is high, the red LED indicator will remain on. Once the battery voltage reaches the appropriate value, the output goes low, puts Q_1 in cut-off mode, and stops the solar cell from charging. The LED then turns green.

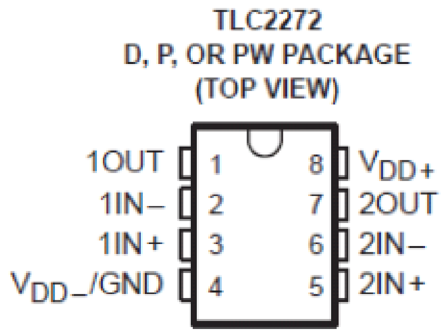

Figure 4: Top View of TLC2272

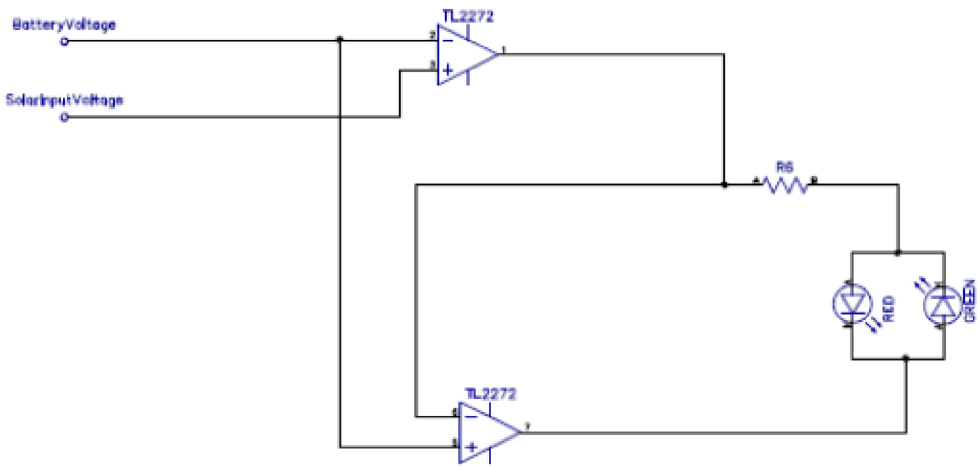

Figure 5: Op-AMP and indication LED set-up

The 3.6W LED light source may be used even when the battery is charging. The solar cell provides the power in this case.

DC-DC converter

A useful added feature is a DC-DC converter chip. This device takes the 12V output from the battery, and steps it down to a 5V, 1W source for USB cell phone charging.

Figure 6: DC-DC converter package (top view)

TYPICAL PERFORMANCE CURVES

Specifications typical at T_A = +25°C, nominal input voltage, rated output current unless otherwise specified.

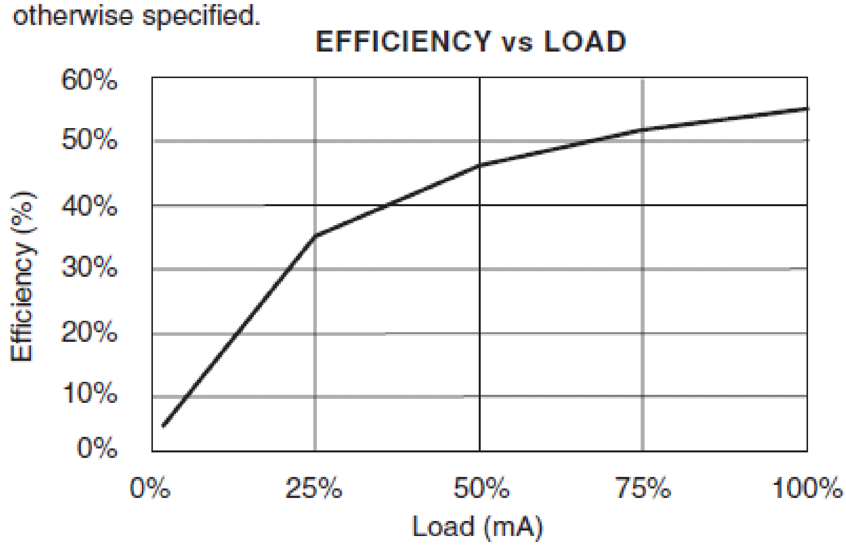

Figure 7: DC-DC converter efficiency vs. load performance

Final Product

It should be noted that with limited resources, the final product for this project is only a prototype of what would actually be implemented in the developing countries.

The design requirements of the lantern call for portability and easy maintenance, so the following factors were considered in the construction process to limit size and enhance ease of use:

- Small battery (limited to battery type and ratings)
- Easy access battery (for replacement)
- Easy access LED bulb (for replacement)
- Easy access to fuse (for replacement)
- Small printed circuit board (area)
- Detachable solar panel
- High packing density (more components, less empty space)

PCB

In designing a printed circuit board, the most important factor is the location of important components. For this application, the most important pins are:

- Solar Power In
- 12V power out
- 5V out
- Fuse
- Potentiometer (VR1)

These five pieces will all be soldered to wires leading to devices/components exterior to the PCB board. Placing these pins in strategic locations will limit the need for long wires, which can become hazardous and inefficient to product performance. Consequently, it is important to decide where the devices will be placed before board fabrication.

The PCB will be placed adjacent to the width (shorter side) of the enclosure to maximize space for the battery. The solar panel, potentiometer, and LED will be external to the enclosure, so their pins are along the perimeter of the PCB. Similarly, the fuse and 5V USB output pins are on the outer perimeter of the PCB. The two pieces will not be located on the outside of the enclosure, but they will

be placed along the sides of the enclosure. The fuse will be located on the length side, and the USB will be on the width side.

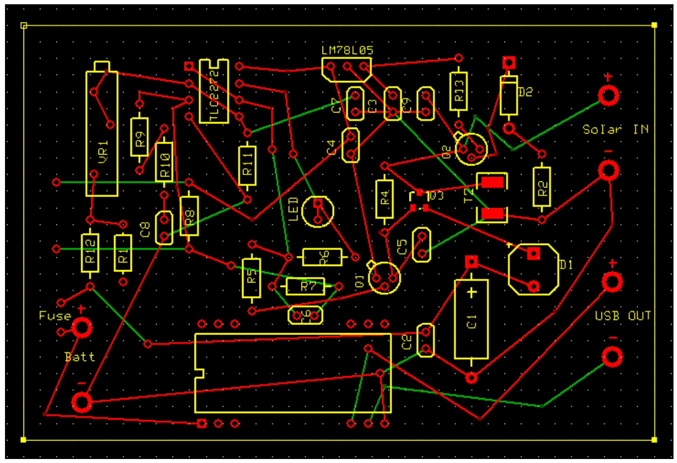

Figure 8: Charge Controller PCB layout

Minimizing cost and empty space, the PCB has dimensions of 3.8x2.5 inches.   The company used to design and fabricate the board was PCBexpress. Figure 8 is the PCB layout generated on the computer. Figure 9 is the physical PCB board fabricated by PCBexpress.

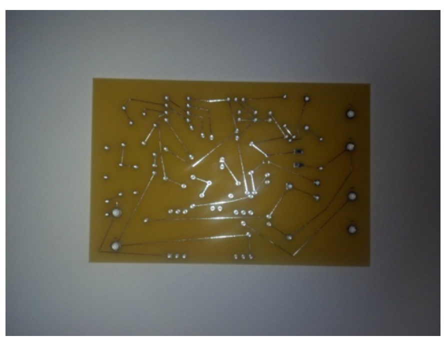

Figure 9: Actual PCB board

Enclosure

The enclosure selected almost fits all of the devices and components perfectly. As shown in figure 10, the battery is mounted in the middle, and the PCB is placed adjacent to the width of the enclosure.

Figure 10: Enclosure

LED fixture

The container for the LED was selected to maximize the lumens output. To avoid losing light, the fixture is fully transparent. Also, the LED emits a relatively, almost negligible amount of heat, so plastic is acceptable to use in the place of glass. The LED bulb can easily be replaced upon opening the top of the container and removing it from the base.

Figure 11: LED fixture

Testing

PCB Test

First, the PCB performance was tested to ensure that the charge controller operates correctly. In full sunlight, the components in figure 12 were tested. Naturally, they met expectations.

Component	Test Performed	Theoretical Value	Actual Value
Voltage Regulator	Input Voltage	12V	11.55
Voltage Regulator	Output Voltage	5V	5.01
Solar Cell/battery	ground-ground potential	0V	1.6 mV
fuse	resistance	0Ω	1.01Ω

Table 9: Component Test Results

Final Product Testing

Most importantly, the final product features were tested in full sunlight. First, the battery was connected to the load with no energy from the solar panel. The significance is to observe how long it takes for the battery to be completely discharged. Table 9 shows the results.

Battery State	Battery Voltage (V)	Percentage of OC value (%)
Fully Charged, Not Connected	13.21	100
Fully Charged, Load Connected	12.5	94.62528388
1 hour	12.02	90.99167298
2 hours	11.53	87.28236185
3 hours	11.15	84.40575322
4 hours	11.22	84.93565481
5 hours	10.77	81.52914459
6 hours	10.12	76.60862983
7 hours	9.3	70.4012112
8 hours	8.52	64.49659349
9 hours(Little or no illumination)	8.2	62.07418622

Table 10: Battery Life Test Results

Based on specs, the battery was expected to last 10 hours. Instead it only provided useful lighting for approximately 8 hours. This is likely due to the power consumption of the DC-DC converter.

Next, the charging capability of the device was tested. In the discharged state, or the state of no useful light illumination, the voltage was recorded. Then, in full sunlight, the panel began to charge the battery and the voltage was recorded each hour. The indication LED remained red in the charging state, and turned green once the charging was complete. Table 9 displays the results.

Battery State	Voltage	Indicating LED color
Discharged	8.6	red
1 hour	9.32	red
2 hours	10.11	red
3 hour s	10.7	red
4 hours	11.38	red
5 hours	11.95	red
6 hours	12.1	red
7 hours	12.3	green

Table 11: battery charging test results

Similar to discharging, the charging process took slightly longer because of the losses in the charge controller components.

Conclusion

This project provided a great lesson on the importance of renewable technologies. Not only do they promote a cleaner environment, but renewable energies are also the key to providing quality, long lasting light to developing countries. As Americans, there are so many luxuries we take advantage of, such as flipping on a light switch for instant light, or plugging in our cell phones to charge three times a day. The things we do mindlessly make us mindless about serious issues across the globe.

The complexity of this project didn't lie in the design. With no design constraints, the final product would not be hard to construct. Instead, the biggest factor that had to be taken into consideration was cost. In order for a solar LED light to compete with similar products marketed in the same industry, it must be cost effective above all. Although the design of my Solar LED Lantern met the performance and size requirements, the cost of production was way too high. This came mostly from using consumer products (batteries, solar panels, LEDs) to power the device. A bigger team (more than one person) or more time for this project would allow getting more information solar energy and LEDs. This insight would enable the custom building of a LED bulb and solar panel, which would lower the total cost tremendously. Also, the high cost of the PCB board is due to low quantities. The more PCBs purchased, the more the price per board approaches negligibility.

I truly believe that in the coming years, developing countries, Africa in particular, will see a rise in the use of solar LED lighting. The kerosene lanterns are still dominating the continent as a solution to the absence of a grid in most regions. As the cost of both LEDs and photovoltaic cells decrease in upcoming years, and the awareness of the dangers of kerosene rises, we will certainly see more quality, clean lighting in the homes of millions.

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Appendices

Appendix A-Senior Project Analysis

Design Requirements

The solar powered LED lantern will have a wide range of uses; however it is primarily targeted to fill the needs of less fortunate persons of developing countries. That said, it is important to consider what exactly they would use the lamp for, and how long.

The “Lighting Africa” initiative serves as the link between private businesses who design green off-grid lighting and communities that desire such products. A video was recently released on the website describing the benefits of LED lighting in Kenya. In short, long lasting illumination throughout the night allows for students to study longer and business owners to operate well past sunset. One individual testified that his new lamp has nearly doubled his income as a bicycle mechanic, all because he can operate his business until midnight rather than 6 pm.

The requirement of the final product design is a well tested LED solar lamp system that can operate at maximum performance for a minimum of nine hours. Most importantly, in order to effectively implement the product in developing countries, production cost must be carefully monitored and kept to a minimum.

Primary Constraints

The biggest challenge of this project, and center cause of many other challenges, is making an affordable product. Just the battery and solar panel alone cost approximately $70, which is about twice the cost of similar products in the industry. Even if the two are purchased in bulk, the unit price drops no more than 20%.

Limited resources play a large role in cost. The following factors are the primary cost issues that were unable to be eliminated:

1. When companies can produce their own enclosures, fixtures, bulbs, etc. the total price for parts decreases significantly.
2. In terms of unit price, buying PCB boards in small numbers is much more expensive than buying very large numbers. If hundreds or thousands of boards or produced at once, PCB fabrication becomes a non-factor.
3. Over the years, the prices of photovoltaic cells and LED technology have decreased tremendously. They may be affordable at the middle class American consumer level, but by no

means affordable to the average citizen in Kenya. As prices continue to drop over the years, both solar and LED technology will be more widely used on a global level.

Other difficulties

1. PCB design- ExpressPCB is a speedy and cheap way to have a printed circuit board fabricated. The software, however, is less sophisticated than some of its competitors. Normally, the click of an icon changes a schematic design to a PCB design. To transition, ExpressPCB requires that the user "link" the schematic, then rebuild the design using netlist of the schematic. This leaves room for much error because the netlist isn't based on the actual connection of the PCB design, but instead the schematic. Also, there is no design rules test to verify errors.

2. Soldering- When performing final tests, a defect was found on the printed circuit board. The cathode and anode of the LED indication light were shorted together. This required using a sharp tool to scratch the wire connecting the leads, and soldering a new wire to the correct location.

3. LED selection- Before beginning this project, little was known about LED bulbs and measurements of illumination. Selecting the right bulb required extensive research of such topics.

Economics

It was striking to find that so many people in the world don't have power. In addition, the use of LED light over dangerous alternatives is minimal at this point in time. According to the Lighting Africa initiative, 99% of Africa still relies on kerosene. The Solar LED Lantern is designed in a time where solar and LED technologies are on the brink of a breakout. It is predicted that the number of people in Africa who use such technologies will skyrocket in the next 10 years as prices drops.

It may appear that only good can come out of LED lanterns illuminating every power-deprived household, but this is definitely not the case. Forcing new technologies and quality products in countries without studying culture and politics can go as far as causing uproar of violence amongst the people or government. Organizations such as Lighting Africa help avoid these issues.

Commercial Production

The Solar LED Lantern is not designed with the intent to make a large profit. Through investors and grants, most of this product would be paid for and distributed to families at little or no charge. If the product is expensive to make, it will not be viewed as a good product to invest in despite superior performance. Based on the prototype cost, and all the reductions in unit price dependent on increased quantity, the following is a breakdown the total price for a Solar LED Lantern:

Assuming that within the first year 100 lanterns are produced:

	Approximate Unit Price
PCB fabrication(ExpressPCB Estimate)	5.54
PCB component total (resistors, regulators, etc.)	3.45
LED bulb	7.99
Solar Panel	27.81
Lead Acid Battery	22.30
DC-DC converter	4.50
light fixture	3
Total =	**74.59**
Price Per Battery Cycle (300 cycles)	**0.25**

Taking production cost into account, the unit price for one Solar LED Lantern would initially sell for $100. This leads to a profit of $2541 for the first year. If the amount of investors increase, so will production and profit. Within the next decade, as LED, battery, and solar panel prices drop, the product should sell for less than $30.

Environmental Impact

Silicon, one of the most abundant materials on this planet, is used to make both the LED bulb and polycrystalline photovoltaic cells. Compared to fluorescent bulbs, LED bulbs are more efficient and friendly to the environment. Most importantly, they are smaller and last much longer, which yields less waste. A typical LED has a life cycle of 50,000 hours (5.7 years), while a fluorescent bulb lasts about 2000 (0.23 years). On the other side, sealed lead acid batteries are hard to dispose of. High in density,

they become useless and a hassle once they go bad. In certain countries, such as Nigeria, the battery's acid is refilled rather than purchasing a new one.

Health and Safety

The Solar LED Lantern will do more to improve health and safety than risk it. The wide use of kerosene lanterns in Africa has detrimental effects on both the environment and the people. Small particles released by gas lamps can cause respiratory illness or even lung cancer. The use of clean, brighter LED illumination in place of kerosene will promote safer and healthier living conditions.

Sealed lead acid batteries are safe under normal operating conditions, but can certainly be dangerous if not used properly or abused. Overcharging the battery can result in an explosion, so it is important for customers to always use the charge controller to revive battery life.

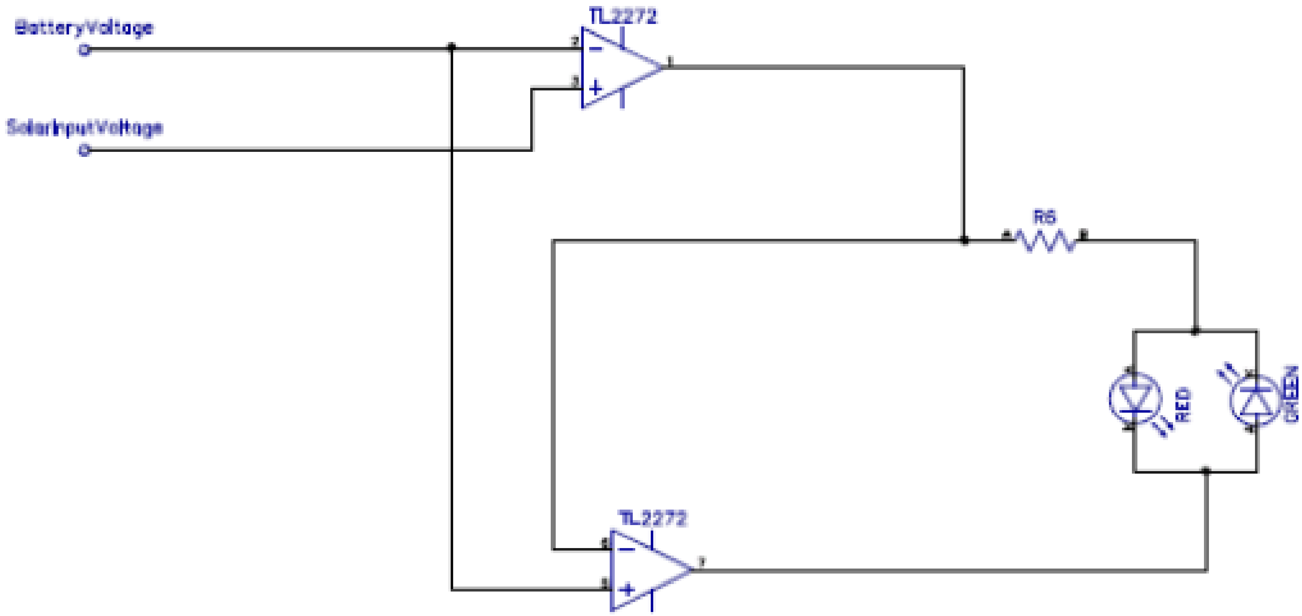
Social and Political Factors

As stated before, implementing new technology in developing countries can cause social and political issues. As most people in the world don't enjoy a disposable income like a great deal of Americans, wherever there is a lack of resources there is violence. Bring in positive doesn't always amount to positive results. Extensive study of culture in a particular region is just as any product specification. The coordination with companies that serve as middlemen, such as Lighting Africa, would ensure the Solar LED Lantern is implemented correctly for the best interest of the people.

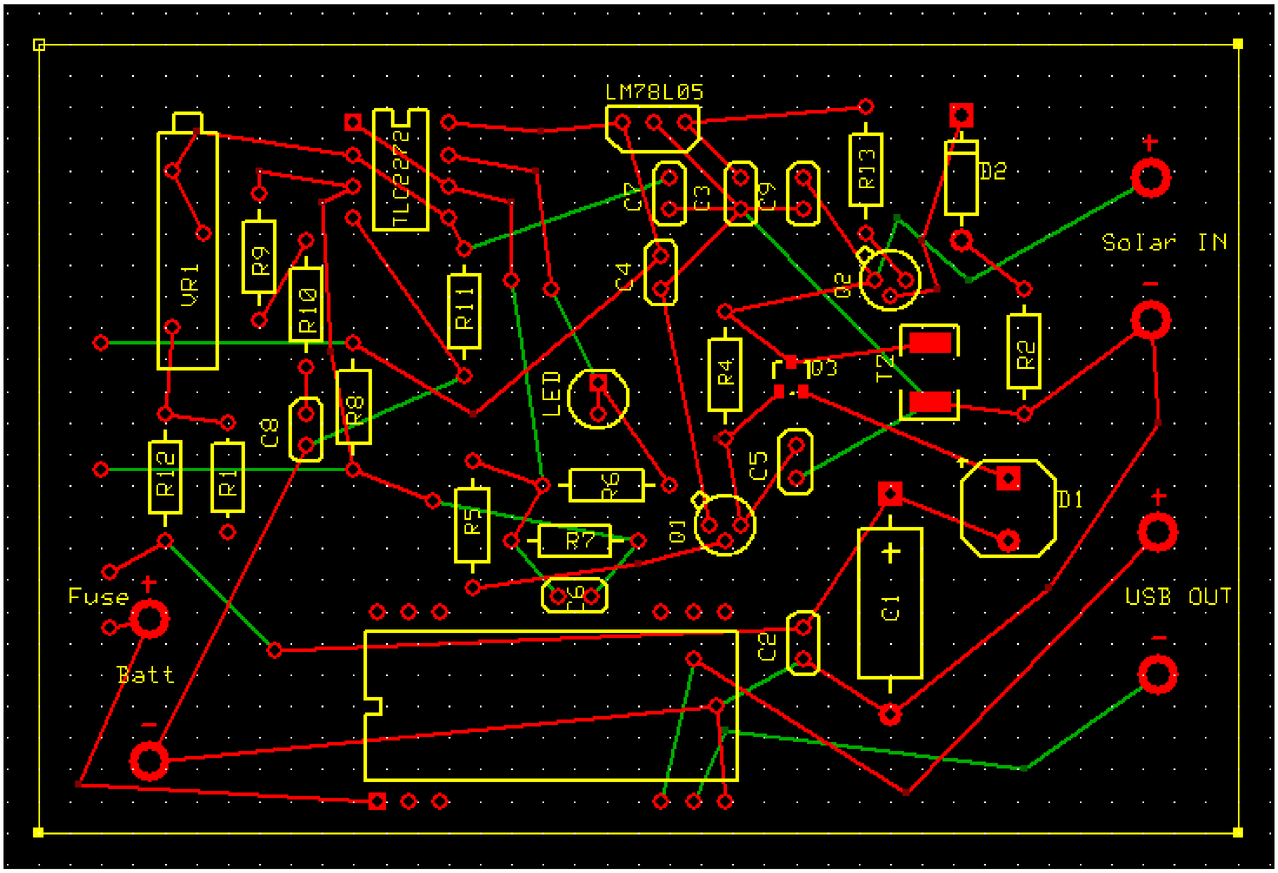
Appendix B: Cost

Item Description	Unit Price	Quantity	Extended Price
NXP TV diode	0.20	1	0.20
Bicolor LED	1.70	1	1.70
Slide Switch	1.80	2	3.60
USB connector	0.52	1	0.52
Murata DC-DC converter	10.49	1	10.49
0.1µF ceramic capacitor	0.34	6	2.04
0.01µF ceramic capacitor	0.17	2	0.34
47µF electrolytic	0.42	1	0.42
Schottky Diode	3.12	1	3.12
Zener Diode	0.07	1	0.07
Linear Regulator	0.66	1	0.66
Op Amp	2.07	1	2.07
NPN Transistor	0.36	1	0.36
PNP Transistor	0.16	1	0.16
Mosfet Rectifier	1.31	1	1.31
Assorted Resistors	0.10	20	2.00
Solar Panel	29.95	1	29.95
12V Genesis Battery	27.99	1	27.99
PCB Board	75.00	1	75
LED bulb	9.95	1	9.95
Enclosure	6.99	1	6.99
Transparent container	5.99	1	5.99
Grand Total:			184.93

Appendix C: Schematic



Appendix D: PCB Layout



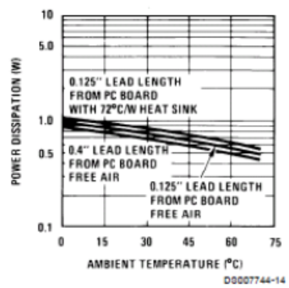
Appendix E: Datasheets

78LO5

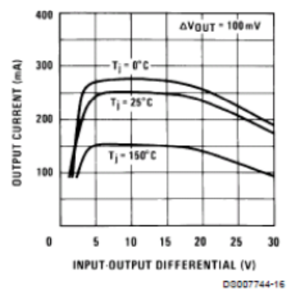
LM78LXX Series

Typical Performance Characteristics

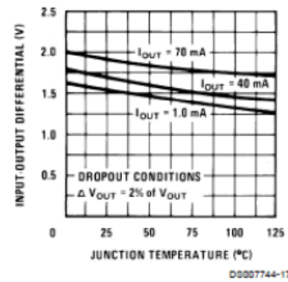
Maximum Average Power Dissipation (Z Package)



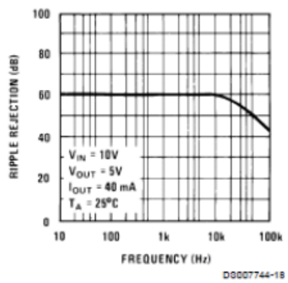
Peak Output Current



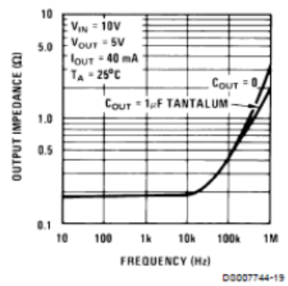
Dropout Voltage



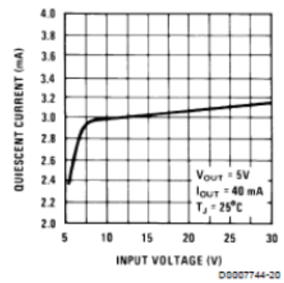
Ripple Rejection



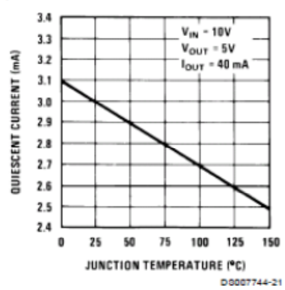
Output Impedance



Quiescent Current



Quiescent Current



IRFR5505

IRFR/U5505

International IOR Rectifier

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	-55	—	—	V	V_{GS} = 0V, I_D = -250µA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	-0.049	—	V/°C	Reference to 25°C, I_D = -1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.11	Ω	V_{GS} = -10V, I_D = -9.6A ④
$V_{GS(th)}$	Gate Threshold Voltage	-2.0	—	-4.0	V	V_{DS} = V_{GS}, I_D = -250µA
g_{fs}	Forward Transconductance	4.2	—	—	S	V_{DS} = -25V, I_D = -9.6A
I_{DSS}	Drain-to-Source Leakage Current	—	—	-25	µA	V_{DS} = -55V, V_{GS} = 0V
		—	—	-250		V_{DS} = -44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	-100	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	—	—	100		V_{GS} = -20V
Q_g	Total Gate Charge	—	—	32	nC	I_D = -9.6A
Q_{gs}	Gate-to-Source Charge	—	—	7.1		V_{DS} = -44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	15		V_{GS} = -10V, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	12	—	ns	V_{DD} = -28V
t_r	Rise Time	—	28	—		I_D = -9.6A
$t_{d(off)}$	Turn-Off Delay Time	—	20	—		R_G = 2.6Ω
t_f	Fall Time	—	16	—		R_D = 2.8Ω, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.)
L_S	Internal Source Inductance	—	7.5	—		from package and center of die contact⑤
C_{iss}	Input Capacitance	—	650	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	270	—		V_{DS} = -25V
C_{rss}	Reverse Transfer Capacitance	—	120	—		f = 1.0MHz, See Fig. 5

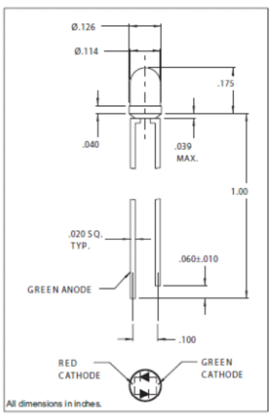
LED

Chicago Miniature Lighting, LLC

Lighting the world since 1910

4301F1/5, F11/17, F15/17 Series Solid State LED Lamps Bi-Color Super Brite T-1 (3mm)

DESCRIPTION AND FEATURES



- Dual chip
- Uniformity of output color
- Wide viewing angle
- White diffused

ELECTRO-OPTICAL CHARACTERISTICS AND RATINGS

PART NUMBER	4301F1/5		4301F11/17		4301F15/17	
Output Color	Red	Green	Red	Yellow	Green	Yellow
Diffusion	Diffused	Diffused	Diffused	Diffused	Diffused	Diffused
Package Color	White	White	White	White	White	White
Test Current (mA)	20	20	20	20	20	20
Forward Voltage Typ. (V)	1.8	2.1	2.0	2.1	2.2	2.1
Forward Voltage Max. (V)	2.4	2.8	2.0	2.1	2.5	2.5
Luminous Intensity Min. (mcd)	3.7	1.1	8.0	5.0	8.0	5.0
Luminous Intensity Typ. (mcd)	12.6	3.7	40	20	20	40
Rated Current (mA)	20	20	10	10	20	20
Peak Wavelength (nm)	660	565	625	590	565	590
Viewing Angle (degrees)	100	100	60	60	60	60
Power Dissipation (mW)	100	100	105	105	105	105
Continuous Forward Current Max. (mA)	30	40	30	30	25	30
Reverse Breakdown Voltage Min. (V)	5.0	5.0	5.0	5.0	5.0	5.0

TLC227x, TLC227xA
Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

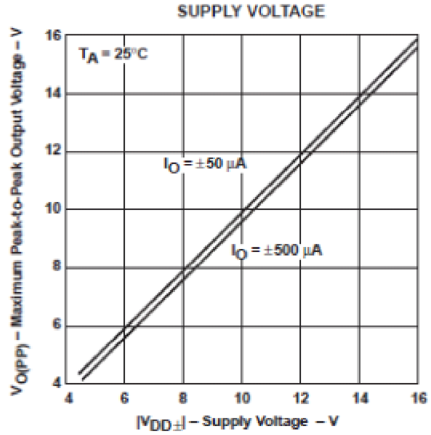
SLOS190B – FEBRUARY 1997 – REVISED JULY 1999

- Output Swing Includes Both Supply Rails
- Low Noise . . . 9 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Common-Mode Input Voltage Range Includes Negative Rail
- High-Gain Bandwidth . . . 2.2 MHz Typ
- High Slew Rate . . . 3.6 V/µs Typ
- Low Input Offset Voltage 950 µV Max at T_A = 25°C
- Macromodel Included
- Performance Upgrades for the TS272, TS274, TLC272, and TLC274
- Available in Q-Temp Automotive
  HighRel Automotive Applications
  Configuration Control / Print Support
  Qualification to Automotive Standards

description

The TLC2272 and TLC2274 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC227x family offers 2 MHz of bandwidth and 3 V/µs of slew rate for higher speed applications. These devices offer comparable ac performance while having better noise, input offset voltage, and power dissipation than existing CMOS operational amplifiers. The TLC227x has a noise voltage of 9 nV/√Hz, two times lower than competitive solutions.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE



The TLC227x, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micro-power dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature, with single- or split-supplies, makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC227xA family is available and has a maximum input offset voltage of 950 µV. This family is fully characterized at 5 V and ±5 V.

The TLC2272/4 also makes great upgrades to the TLC272/4 or TS272/4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices.

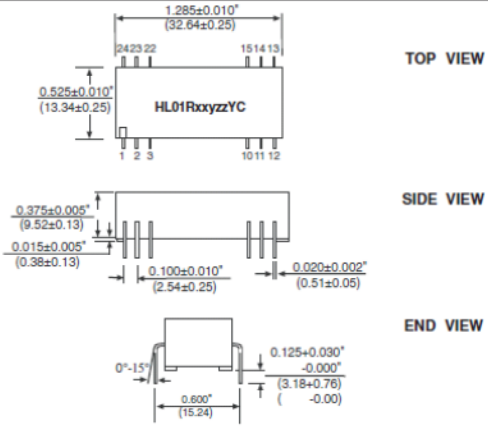
If the design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

Murata Power Solutions

HL01RYC

1 Watt Regulated DC/DC Converter

MECHANICAL Package/Pinout "Y"



DIP PACKAGE

NU = Do Not Use.

NC = No Internal Connection.

Duplicate pin functions are internally connected.

All dimensions are in inches (millimeters).

GRID: 0.100 inches (2.54 millimeters)

Typically Marked with: specific model ordered, date code, job code and Logo.

Pin base metal is phosphor bronze. Pin finish is matte tin (100-300 microinches) over a nickel barrel layer (5-40 microinches).

PIN CONNECTIONS

PIN#	SINGLES	DUALS
1	+VIN	+VIN
2	NU	-VOUT
3	NU	Common
10	-VOUT	Common
11	+VOUT	+VOUT
12	-VIN	-VIN
13	-VIN	-VIN
14	+VOUT	+VOUT
15	-VOUT	Common
22	NU	Common
23	NU	-VOUT
24	+VIN	+VIN

THROUGH-HOLE SOLDERING INFORMATION

These devices are intended for wave soldering or manual soldering.

They are not intended to be subject to surface mount processes under any circumstances.

The normal wave soldering process can be used with these devices where the device is subjected to a maximum wave temperature of 260°C for a period of no more than 10 seconds. Within this time and temperature range, the integrity of the device's plastic body will not be compromised and internal temperatures within the converter will not exceed 175°C. Care should be taken to control manual soldering limits identical to that of wave soldering.

Murata Power Solutions

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