The SHOT® Pocket Charger

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Abstract: The objective of the Pocket Charger Project was to demonstrate a small, lightweight Smart Charger capable of recharging the 16.8Vdc/8 amp-hour LI-7 Land Warrior Battery. The Pocket Charger was designed to operate from input power sources providing only DC voltages such as a solar panel, 24volt Zinc-Air Battery, and the HUMVEE® power system. Because the Pocket Charger conforms to the Smart Battery System (SBS) industry standard, it can charge any Smart Battery that conforms to the SBS system (within certain limitations).

Through this device, we successfully met the DOD challenge to produce a small, lightweight SMBus compliant charger for the individual soldier. It is capable of accepting a wide range of DCV power sources for the specific purpose of charging the LI-7 Land Warrior Battery or other Lithium Ion batteries having similar input requirements. In due course, the Demo Unit will become the framework design for the future MIL-SPEC compliant Pocket Charger.

Keywords: SMBus; Lithium Ion; Li-Ion; Smart Charger; Smart Battery; Power Management System; Future Soldier; Land Warrior; SBS; Charger; Battery

Introduction

The specific goals of the Pocket Charger program were to demonstrate the following:

- Charge using SBS Level 2 architecture and maximum battery current of 2 amps.
- Operate from a DC voltage range of 10 to 32 Vdc.
- Operate at temperatures from 0 to 50 degrees Celsius.
- Weigh less than 500 grams (1.1 pound).
- Have a volume of less than 20 cubic inches.
- Provide illuminated indicators for input power status and charging activity status.
- Use LEMO connectors to provide cabling for power connections and the LI-7 Battery.
- Demonstrate charging with a solar panel, zinc-air battery, and 10-32vdc power sources.

Pocket Charger Operation

The underlying technology of the Pocket Charger and LI-7 battery is quite complex, but the operation of the Pocket Charger is easy. Simply connect the Pocket Charger battery connection to the LI-7 and apply DC power (from 10 to 32vdc) to the Pocket Charger via its power input connector/cable and charging will automatically begin and end when the LI-7 is fully charged.

The Pocket Charger can fully charge a depleted LI-7 lithium ion battery in less than 4.5 hours. This is energy storage of approximately 7339 millamp-hours (mAh). The charging time is independent of the input voltage supplied to the Pocket Charger. As long as the Pocket Charger's DC power source can supply the necessary power* in a range between 10 and 32 volts DC, the Pocket Charger will fully charge the LI-7 in less than 4.5 hours**.

** The Pocket Charger can require up to 48 watts of power to supply a 2 amp charging current to the LI-7 at the peak of the charging cycle power curve (at minimum input voltage and polarity protection diode installed).*

*** Charging times can vary when using the solar panel as a power source (see section on solar charging).*

Figure 1. SHOT® Pocket Charger Demonstration Unit as Delivered to U.S. Army CECOM RDEC, Ft. Monmouth, NJ for Test and Evaluation

Pocket Charger Features

Smart Battery System Level 2 Architecture: In its current demonstration configuration, the Pocket Charger utilizes SBS Level 2 software architecture. This requires the Smart Battery to broadcast charging commands to the Pocket Charger via the SMbus. As defined in the industry recognized Smart Battery Charger Specification, "*The Level 2 Battery Charger interprets the Smart Battery's critical warning messages, and operates as a SMBus™ slave device that responds to charging voltage and charging current messages sent to it by a Smart Battery. The charger is obliged to adjust its output characteristics in direct response to the charging voltage and charging current messages it receives from the battery. In Level 2 charging, the Smart Battery is completely responsible for initiating the communication and for providing the charging algorithm to the charger. The Smart Battery is in* *the best position to tell the Smart Battery Charger how it needs to be charged. The charging algorithm in the battery may simply request a static charge condition or may choose to periodically adjust the Smart Battery Charger's output to meet it's present needs."*

Volume: The Pocket Charger enclosure is a COTS plastic enclosure chosen to demonstrate the volume requirement of less than 20 cubic inches.

Weight: The Pocket Charger's overall weight is considerably less that the 500 grams maximum limitation. This weight includes the Pocket Charger assembly with battery cable pigtail, and also the 12" power cable. Note - 33% of the Pocket Charger's weight is from the enclosure, thus making the enclosure a prime target for weight reduction.

Temperature: SHOT evaluated the Pocket Charger operation at 0 degrees C, room temperature, and with thermal cycling between 30 and 50 degrees C with successful operation at all temperatures. Based on thermistor readings from the warmest semiconductor components, the Pocket Charger demonstrates continued operation at temperatures as high as 50C (122F).

Pocket Charger Applications

Charging with the BA-8180/U Zinc Air Battery: The Pocket Charger is designed to use the BA-8180/u 24v zinc-air battery as one of its many input power sources. SHOT evaluated the Pocket Charger's performance with the zinc-air battery by charging the LI-7 four times from a single zinc-air battery. Since the zinc-air battery was able to supply all the power required for a normal (2 amp charge current) charging session, the results were the same as if a 24 volt DC power supply had been used. Table 1 shows the results of each charging session. The graph in Figure 2 shows typical voltage and current characteristics of the zinc-air battery during a charging cycle using the Pocket Charger and LI-7 battery.

Table 1. Charge Data using Zinc-Air Battery Power Source

	Starting milliamp-hours	Ending milliamp-hours	Milliamp-hours stored	Time to 100% Capacity
Cycle#1	111	7456	7345	4:01
Cycle#2	44	7456	7412	4:06
Cycle#3	77	7200	7123	4:01
Cycle#4	14	7492	7478	4:16
Average			7339	4:06

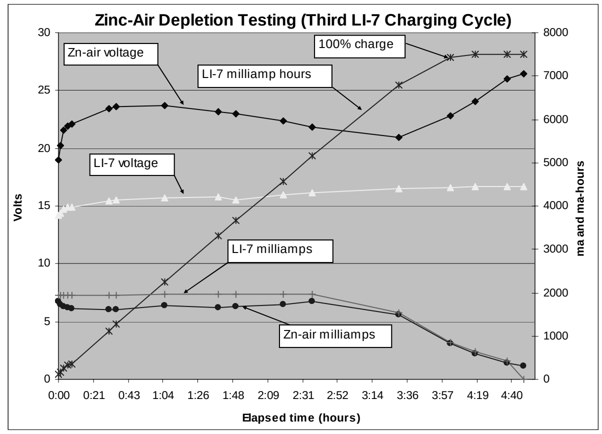

Figure 2. Voltage and Current characteristics of an LI-7 charge cycle using the Pocket Charger with a Zinc-Air battery as the power source

Charging with a Solar Panel: The Pocket Charger was also designed for a solar panel input as an alternative power source to the zinc-air battery and dc power supply. In order to demonstrate solar powered charging with the Pocket Charger, SHOT chose the Global Solar Energy solar panel rated at 12vdc output. The electrical characteristic of this solar panel works well with the Pocket Charger's input circuitry.

The power output from a solar panel can vary dramatically due to factors such as:

- Time of Year
- Latitude
- Temperature
- Panel Orientation
- Cloudiness

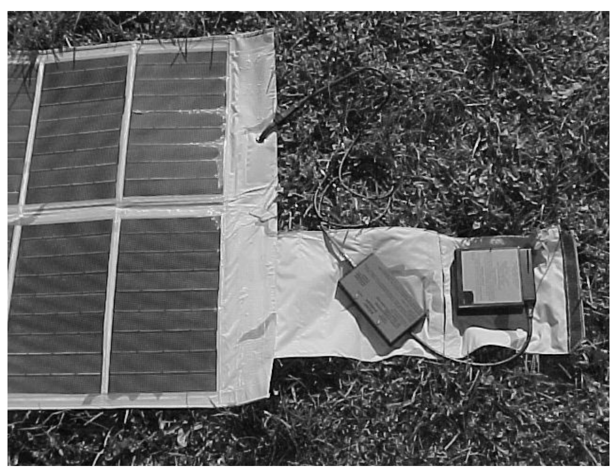

Figure 3. Pocket Charger with solar panel power source

The maximum power drawn from this solar panel in Indiana during the month of November in ideal conditions was approximately 25 watts. This is not sufficient power to maintain a 2 amp battery current during the constant current phase of the charging cycle. Therefore, the Pocket Charger enters an analog mode designed to harvest whatever power is available from the solar panel and deliver it to the LI-7 in the form of a charging current that varies with the changing power output of the solar panel. In this mode, the charging current is less than 2 amps and the charging time is longer than 4.5 hours. Larger portable solar panels are available which through the use of the Pocket Charger; provide ample power to charge the LI-7 in less than 4.5 hours with favorable conditions.

Charging with Automotive Electrical Systems: The HUMVEE® and other military vehicles use a 24/28 volt dc power system. The Pocket Charger can easily operate from this voltage because it falls within the Pocket Charger's input power range of 10 to 32 vdc. However, automobile electrical systems (including 12 volt automotive systems) can exhibit voltage transients at potentially damaging power levels due to alternator transients, jump starting, and reverse battery conditions. In order for the Pocket Charger to demonstrate compatibility with automotive electrical systems, a transient voltage suppressor network was developed.

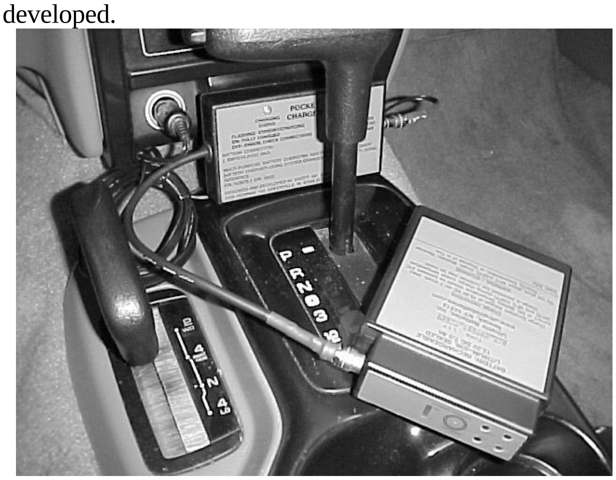

Figure 4. Pocket Charger operating from Vehicular Power Source

The Next Generation Military Version Pocket Charger

The Pocket Charger Project was a feasibility study to determine if a small, wide-range DCV Pocket Charger could be developed within the parameter defined by the customer. Thus, only in-stock, off-the-shelf components were used and there was no dedicated tooling designed or purchased. Based on SHOT's evaluation of the Pocket Charger's design and performance, a high performance MIL-SPEC compliant version can be implemented with the following features.

Volume: The volume of military version of the Pocket Charger can be reduced considerably using a custom designed aluminum enclosure while using the same connector and pigtail scheme.

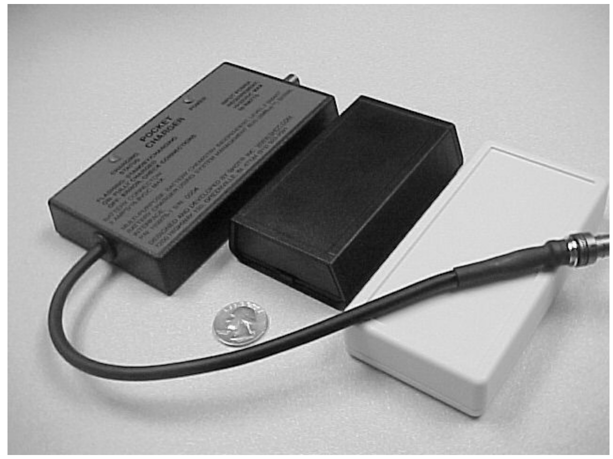

Figure 5. Potential Next Generation Military Housings

MIL-STD-810 Environmental Testing: By using an aluminum enclosure and a thermal potting compound, a military Pocket Charger can withstand extremely high temperatures and the harsh environmental testing required by MIL-STD-810.

Electromagnetic Interference: Once an EMI/EMC requirement is specified, the aluminum enclosure along with filters and shielding will enable the Pocket Charger to meet military EMI/EMC requirements.

Software Features: Incorporate Smart Battery System (SBS) Level 3 charging architecture tailored to accommodate special needs. An optional SBS Level 2 architecture can be used for applications not requiring Level 3 special features.

POCKET CHARGERS with other voltage and power ratings: The charging time of the LI-7 battery is primarily a function of the current supplied to it during the constant current phase of the charging cycle. Increasing the charging current will decrease the charge time. Table 2 below shows typical charging times for the LI-7 battery as a function of charging current.

Table 2. Charging times versus charging currents for the LI-7 battery

Battery Charge Current Applied	Approximate Charge Time
1 amp	8.0 hours
2 amp	4.0 hours
5 amp	2.75 hours

The application for a military version of the Pocket Charger may require:

- A charge current greater or less than 2 amps.
- A dc input voltage range different from 10-32vdc.
- An AC powered Pocket Charger.

SHOT can modify the Pocket Charger design to meet any special electrical requirements.

The SHOT Smart Charger

In addition to the pocket charger, SHOT right now has a high power, high fidelity Smart Charger Prototype that can charge the LI-7 battery in 2.75 hours by using a 5 amp charge current. This versatile prototype can be powered from 24vdc *or* from 100-250 VAC power sources. SHOT is currently under contract with the U.S. Army to develop a military qualified 4 to 5 amp Smart Charger in a package that is 50 cubic inches, 1.5 pounds, and compliant to MIL-STD-810. Although this device is tailored for individual soldier applications, it is designed to charge up to ten LI-7 batteries in series from a single input.

Pocket Charger Performance Summary

The project objectives and methods of demonstration are summarized in Table 3. The Demonstration Unit clearly meets or exceeds each objective levied on the project by the customer.

Table 3. Pocket Charger Performance Summary Chart

Objective	Method of Demonstration
SBS Level 2 Charging at 2 amps	Demonstrated by placing the LI-7 in broadcast mode and monitored charge current with TI EV2000 SMBus monitor.
Operate from 10 to 32vdc	Demonstrated with variable lab power supply.
Operate from 0 to 50 degrees C.	Operational at 0C, 25C, and cycling between 35C and 50C.
Weight less than 500 grams	The Pocket Charger assembly weighs less than the maximum.
Volume less than 20 cubic inches	The enclosure volume is less that the maximum. Military version will be further reduced.
Provide illuminated indicators	Green light emitting diodes indicate power and charging status. Military model will possess LED blackout option.
Use Lemo connectors	Lemo 0F and 1F connectors were employed.
Charge with Zinc-Air Battery	The LI-7 was fully charged 4 times with a single Zn-Air battery.
Charge with Solar Panel	The LI-7 solar charging session was documented with detailed graphs contained in this report.

Conclusion

The SHOT Pocket Charger was successfully demonstrated to and verified by the U.S. Army CECOM RDEC, Ft. Monmouth, NJ on December 11, 2003. The charger met all objectives and has been considered a candidate for additional funding to support the next phase of development. Ultimately, the goal is to develop an individual issue Pocket Charger designed specifically for field applications. Additionally, the high performance characteristics of this charger combined with its extremely low profile make it a desirable candidate for consideration as a single/multiple charge unit for military vehicle applications (HUMVEE, STRIKER, etc.).

Design strategy and specific performance analysis can be found in the Pocket Charger Final Report. This report contains contractor proprietary information and is only available upon written request to:

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