

AC 2007-1688: AC-POWERED BACKPACK PROJECT

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AC Powered Backpack Project

Abstract

The human powered backpack¹ was developed by four senior mechanical engineering majors at Rice University. The backpack was targeted for students in rural third world countries where electrical power is rare or non-existent at home. The concept was to have local power for educational devices available at the student's home to augment classroom instruction.

This project required collecting data from schools in different third world locations to establish the need. The project was done in the students' capstone design course and in conjunction with the Schlumberger Excellence in Educational Development⁵ (SEED) Foundation. The SEED program provides support to schools in many of the countries where Schlumberger Ltd. operates (currently 137 schools in 32 countries).

The original backpack had a small hand-cranked generator. This original project was described in a paper for the 5th annual ASEE Global Colloquium on Engineering Education⁶. Later three human powered backpacks were field tested at a rural SEED supported school in Mexico. The power capability of this unit was found to be limited so a redesign was undertaken to upgrade the unit with more power. The electronics in this backpack have been enhanced with the capability to charge the batteries with AC power at a community location such as a school and then be used for educational purposes in a rural home environment which does not have electrical power available.

The backpack has a rechargeable battery pack and can serve as a general purpose educational power source. This unit can provide power for a small reading lamp, a SEED provided programmable logic board for experimentation by students (*i.e.* "Go-Go" Board³), hand-held educational electronic devices (*e.g.* a PLS 1000⁹), and a small transistor radio. The lamp is an LED light that can clip onto a textbook for studying after dark. This capability of reading after dark without candles or firelight greatly enhances the student's opportunity to learn in a remote home environment.

The new unit will have capability of powering items with up to 5 volts DC and 200 mill amps power requirements. The enhancement of having AC power charging capability greatly increases the power capability of the unit and extends its usefulness to many educational devices that are currently available.

Since the original project was completed, we have made a major change in the administration of the capstone projects for the current year. This year we have incorporated cooperative learning techniques of the capstone course which address many of the issues relating to teams involving multiple departments. These changes have strengthened the course and addressed the goals of our capstone design experience⁸. Cooperative learning has been shown to improve student-faculty and student-student interaction, information retention, higher-level thinking skills, motivation to learn new material, teamwork, interpersonal skills, and communication skills, all of which encompass the goals of our capstone design course⁷.

Introduction

Mechanical engineering seniors at Rice University are required to take a capstone design course² when pursuing a Bachelor of Science degree in mechanical engineering. The students choose projects from a list of suggested topics provided by the faculty or propose a topic of their own which must be approved by the instructor. The students form teams of 3 to 5 people and are encouraged to include students from other participating engineering disciplines as appropriate for the topic chosen. The capstone course is designed to allow the students to use their undergraduate course work in a practical application project. There are various topics available to the students and range from competitive industry sponsored projects to medical related projects.

During the 2005-2006 academic school year, two project topics were suggested by the SEED Foundation. The SEED program provides support to schools in many underdeveloped countries (currently 137 schools in 32 countries). The recent emphasis has been to provide and support computer labs in these schools. One project suggested by SEED was to provide power for computer labs in these schools where electric power is unreliable or non-existent.

This project like all the projects in the capstone design course is intended to be open-ended so there is often evolution of the project topic. The students evaluated the energy required to power the older type desk top computers and felt it would be difficult to provide significant power for a computer lab. After doing a background investigation of the power requirements, the team began to consider other educational electric power needs in underdeveloped countries. The team purchased some hand powered units like hand-cranked flashlights, etc. These items were “dissected” to evaluate the power generation approach used. The generator and rectifying systems were noted and provided a model for the final development. The students leaned toward a general purpose power source rather than the single purpose items like the hand-cranked flashlight which are quite limited in power capability. After brainstorming the possible power issues, the project topic evolved to a modest power pack that would fit into a typical student backpack¹. The SEED foundation has provided backpacks to many students in their program so this seemed like an enhancement to what was already being done. The students targeted powering small educational hand held devices (*e.g.* a PLS 1000⁹), a programmable logic board (*i.e.* Go-Go boards³) which had already been provided to many schools by SEED, and a small study light. The group felt that a text clip-on study light for students to use at home would be a very useful and practical application of a small power pack built into a backpack. The power requirement for this type of LED light is very low, but it would be very adequate to illuminate a page of text for studying after dark. To compensate for lack of unreliable or non-existent electric power at the students’ homes, they decided to make a manually charged power unit for the student backpack.

The students made up a list of questions for the schools. Due to logistical problems, these questionnaires did not get translated and sent to the schools in time to provide feedback in the formative stages of the project. The inputs came largely from the local SEED representative’s experiences in his travels.

Project Development

Once the specific project topic was defined, the students worked on the specifications required for a human powered backpack. One target was to power a small LED light with mounting clip

capable of attaching the light onto a text for study at home after dark. The power consumption of the LED light is very small, and the goal was to provide light for 10+ minutes with 1 minute of charging the power pack in the backpack. The power pack needed to be small with regard to a typical backpack. The prototype was contained in a box with dimensions: 7 X 3 X 1 7/8 inches (17.8 X 7.6 X 4.8cm). The power unit has the crank handle external to the box dimensions (see figures 3 and 4).

Additionally the backpack was intended to power small educational handheld devices. These devices typically are powered with 4-5 volts so the design was to have four 1.4 volt storage batteries of the “AA” size. Fully charged the batteries used can provide 4.8 volts at 100 mill amps for 5 hours⁴.

The cost target for the power pack unit was \$25 US, but the 100 quantity estimate is more like \$38 US. The prototypes cost considerably more as some of the components were “cannibalized” from other manually charged units e.g. the handle came from a hand-cranked flashlight. Appendix B shows the cost for the backpack in a quantity of one and the estimated cost in a quantity of 100.

In the spring of 2006, the group developed the original prototype unit. This included designing the electric circuit and the mechanical aspects of the generator cranking mechanism which included a generator (alternator) and the gear train for the crank attachment. A box for the power unit was designed and built out of Plexiglas. The students laid out the patterns for the backpack and sewed it from heavy canvas fabric. A special pocket in the backpack was designed to house the power pack (see figure 1 and 2). This unit was small enough to leave room for the typical back pack uses of carrying books, etc. Four backpacks with power packs were built after some evaluation of the initial prototype backpack. Minor changes were made in the subsequent backpacks. These backpacks were assembled for a field evaluation at a school in Mexico.

Original Prototype Design Features

Figure 1 shows the backpack on a student. In this mode, the human powered backpack appears and functions as a normal backpack. The power unit fits into a special pocket inside the backpack. The crank protrudes though the side wall of the backpack and folds so the handle fits into a button hole back into the backpack. Two flaps can be joined together with Velcro to cover the crank. Figure 2 shows the backpack with the flaps opened to expose the crank. In this mode the crank can be rotated to charge the batteries. The power pack unit itself is shown in figure 3. The clear plastic box is held in a pocket in the backpack. The crank is shown in the position for charging the power pack. In figure 4 the power unit is shown with the lid removed to show the inner components which include the alternator with diode rectifiers, voltage regulator circuit board, rechargeable batteries, and a switch for powering components or charging the batteries.

Field Evaluation

A total of five prototype backpacks were assembled and three were sent to a SEED supported school in Villa Hermosa, Mexico. The backpacks were used by students during an afternoon session with the SEED representative. Although there was no long term evaluation of the backpacks, in general, they were well received by the students at the school. The ergonomic

features of the backpack/charging system were noted as appropriate for ease of use by the students.

Project Review

Team review of the project at the end of the capstone design course in May, 2006 noted several improvements. The human powered backpack was designed for conditions where there is no electrical power service at the students' homes and possibly no power at their school from a typical electric power grid. This approach meant that the power pack relied only on mechanical power for charging the batteries. Since the original concept was to have a general power pack for use with multiple small electronic devices, it became clear that the manual charging was a limiting factor. The manual charging was not providing the charging capability to power some of the additional devices like the Go-Go board³. After the field evaluation, it was decided a significant improvement would be to make the power unit capable of charging the batteries with electric power from a standard electric power grid which often would be available at the school. When fully charged the NI-Cad batteries can give 100 mill amps for up to 5 hours⁴. This is much more power than can be provided using the manual charging capability. Since the existing charging system used an alternator, the power pack had the components to rectify AC power and charge the batteries. The only added requirement was to have a transformer to take the AC electric service voltage down to 6 volts used in the battery pack. This would service cases where the school has power, but the student doesn't have power at home. This would greatly extend its usefulness to higher power consumption requirements (for a Go-Go board, etc) and longer powered sessions at home than was practical with hand cranking. The hand-cranking system really provided adequate power only for the LED light and in that service, gives a couple of minutes of light for several minutes of hand-cranking. The AC charged system could easily give several evening sessions from one charging session. . Nominally to fully charge requires 10 to 15 hours with 6 volts at 50 milamps⁴, but a partial charge would provide power for the anticipated needs for an evening study session. The lack of continuous AC power at the school should not be a serious problem since charging the system can be done with intermittent power. It was clear that the AC charging capability would greatly enhance the usefulness of the backpack power pack for study at home.

Although the power pack is not large and leaves adequate room for the typical back pack needs, some improvement in miniaturization could be achieved with further development. It is estimated that the unit size could probably be reduced by 50% to allow more book storage room. Due to time constraints and availability, the alternator used in this project has a low power output. A larger electrical power output alternator would enhance the mechanical charging capability of the power unit. This improvement was considered less necessary than the AC charging capability.

There was not enough time to complete the addition of AC charging capability in the capstone course and it did not have enough scope to be a project for the next year, so this enhancement was done outside of the capstone course. Two electrical engineering students were enlisted to work on this improvement.

This extended project work consisted of evaluating the NiCad battery charging requirements⁴, choosing a AC power adaptor to rectify the local AC power, and determining the required circuit

upgrade as needed. These students have chosen an adaptor and redesigned the circuit for externally charging the batteries. Generally the existing components were adequate for this added capability. The new unit will be field evaluated this spring. It is anticipated this will be a significant enhancement for the original project.

Lessons Learned

Overall, this project fit the course requirements, but would have been better if it included a multidisciplinary group *i.e.* some electrical engineering students on the team. We generally have multidisciplinary teams, but in this case we relied on technicians in other departments for support of the students. Reflecting on the overall conduct of the project, it is clear that having more strength in electrical engineering would have been better for the project progress.

We have made a major change in administration of the capstone projects for the current year. We have incorporated cooperative learning techniques in the capstone course which address many of the issues relating to teams involving multiple departments⁸. Cooperative learning has been shown to improve student-faculty and student-student interaction, information retention, higher-level thinking skills, motivation to learn new material, teamwork, interpersonal skills, and communication skills, all of which encompass the goals of our capstone design course⁷.

Conclusions

- The project team developed a small power source contained in a backpack to enhance the students' education in rural areas which do not have reliable electric power.
- This project provided an excellent design development experience for the four mechanical engineering students. It followed the classic design procedure of defining the problem, brainstorming, determining specifications, locating components, making other components, assembly, testing, and field evaluation.
- The addition of AC charging capability greatly extends this educational device's usefulness.

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APPENDIX A PICTURES OF BACKPACK COMPONENTS



Fig. 1: Overall back pack on student. Fig. 2: Back pack flap open to show crank

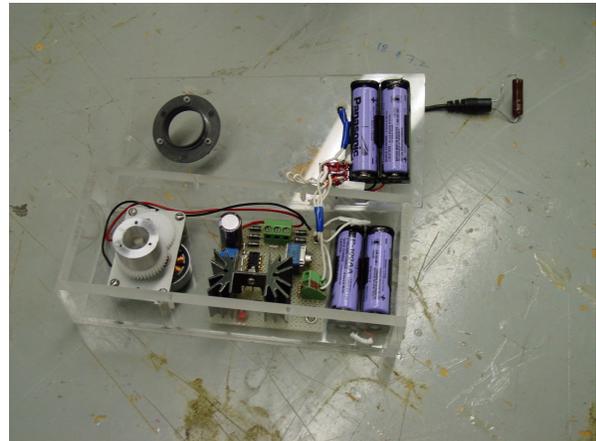


Fig. 3: Power pack Fig. 4: Power pack with lid off

APPENDIX B

Cost Estimate for the Backpacks in Quantity

Total Costs for complete system per unit

Item	1 unit	100 units
Backpack	\$89.85	\$40.89
Generator*	\$1.82	\$1.82
Batteries	\$9.44	\$7.52
Crank**	\$29.99	\$2.50
Housing	\$10.00	\$1.95
Electrical Components	\$31.56	\$24.72
A C Power adapter (est.)***		
TOTAL	\$172.66	\$79.31

*The generator was not available in a quantity of one; the single unit price is the generator price in a quantity of 100.

** The single unit cost was for a complete hand cranked flashlight used to supply the handle for the prototypes.

*** The additional cost of the A C charging capability is estimated as:

Quantity of 1 unit\$8.50

Quantity of 100 units....\$5.23