Above: A portable solar-powered system runs computers and communications equipment. The system recharges from the sun, an automobile, or from the electric grid wherever you are. Photo by Richard Perez

Photovoltaic Power for the Permanently Portable

Richard Perez

I really missed my computer on our trip to Colombia last year. So much of what I learned ended up on scribbled notebook pages. So much of what I had to teach was stuck inside a computer four thousand miles away. I decided then and there that a portable computer was for me. Here's a small PV system that tucks away in a large briefcase and frees your computer, radios, printer, or what-not, from the tyranny of the extension cord.

Enter the Portable Computers

Our small Macintosh PowerBook is a delightful and fast tool. This small computer allows us to take Home Power's databases and renewable energy information anywhere. The problem is that the built-in battery only lasts about two hours before requiring recharging. This is scarcely enough time to work through a long aircraft flight, much less a few weeks in the Andes. At Energy Fairs and events, folks have often asked us for a small PV system design that would allow the new generation of portable computers to go where the power lines don't. I remember one gentleman in particular. He was employed by the USGS doing mapping in Alaska. He lived out of a backpack and his range was limited by how many PowerBook batteries he could carry. He would spend all day gathering survey data and feed this data to his PowerBook at night. Every few days he returned to his base camp and ran a small generator to refill his regiment of PowerBook battery packs.

Over the years I have wanted to take a variety of electric tools into the outback. But when it really comes down to it, there are really only two tools that justify this degree of expense and effort — computers and communications. Communications turns out to be an easier to solve solar problem than is the computer. Radios and small TVs consume only small amounts of power, usually 10 to 40% of the power required for a portable computer. The system described here will not only support intense use of a portable computer, but will also run a radio or small TV receiver. This system will support CB and Amateur transceivers. I can run my two meter handytalkie (ICOM IC-2SRA), charge an extra HT battery, and run the computer at the same time!

Space — the final frontier

Two things I've learned about traveling in the outback — go compact and go rugged. This portable PV system had to be small enough to hump up mountain trails and rugged enough to survive a moose attack under four feet of water. These two design criteria constantly clashed during the fabrication of this system. When it came to a hard choice between lightweight and ruggedness, I chose ruggedness.

Power Sources

The successful traveler is an opportunist. When the food is good, it's time to eat. When the bed is soft, it's time to sleep. The happy traveller stores his energies for times when the living isn't so easy. I wanted this PV system to be just the same — an opportunist. This system will feed from virtually any electrical power source — a PV module, a car (12 VDC), and/or the local electric grid (either 120 vac, 60 Hz. or 240 vac, 50 Hz.).

Travelers with special feeding requirements often go hungry. I decided to base this portable system on the most common form of power in the world — 12 Volts DC. Every country in the world uses automobiles and they are all 12 VDC systems. Twelve Volt PV modules, batteries, and inverters are readily available and inexpensive.

The PV Modules

The PV modules used in this portable system must have a high power to weight ratio. I used a Solarex MSX-10, 10 Watt PV module (650 mA at 15.5 VDC) that weighs about 1 pound. This module uses no glass and is rugged enough to survive on the decks of sailboats. I also put an old Sovonics 6 Watt fold-up PV module in the case and can power the system with both modules if needed. Ideally two of the Solarex MSX-10 Lite PV modules would be better for this system. Since I already owned the trusty Sovonics fold-up module, I used it instead.

Recharging from a Car

This system is designed to plug directly into any car's cigarette lighter socket. An automotive battery/alternator is a very effective recharging source for this portable system. The system will both recharge its internal battery and operate the loads from a resting car battery (no alternator running). The regulator provides overcharge protection if the car's alternator is operating.

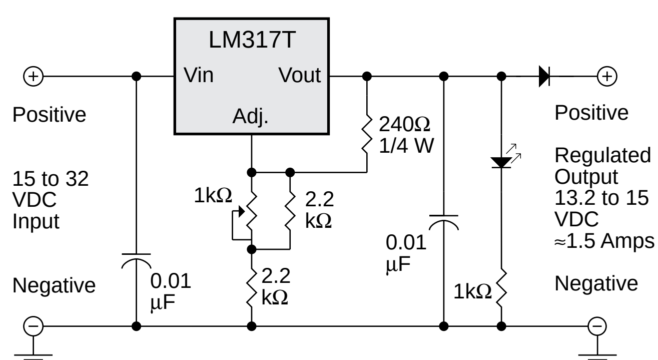
Recharging using 120 vac

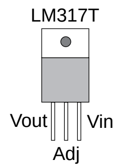
A small 120 or 240 vac "wall cube" type power supply recharges the system when the grid or a generator is available. I used a supply rated at 500 milliAmperes 14 Volts DC. Actually this supply has an open circuit voltage of 16.8 VDC and very nearly replicates the MSX-10 Lite PV module as a power source. This wall cube is about 3 inches on a side and weighs 8 ounces.

The Regulator

I had to design and build the regulator because no commercial model was available. The system is tiny with maximum recharge currents in the neighborhood of 1.2 Amps. The regulator should be able to feed on a variety of power sources and not ever damage the battery.

This regulator is simple, versatile, and bullet-proof. It is capable of controlling the voltage of the PV module, the incoming car battery power, or the wall cube ac/DC power supply. I used the LM 317T regulator (Radio Shack # 276-1778 for $1.99) not because it is efficient, but because it is virtually indestructible. The LM 317T contains internal current limiting (1.5 Amps), overtemperature shutdown, and short circuit shutdown. Since the regulator is inefficient, a manual switch is provided so the the bulk of the recharging can bypass the regulator. The system uses a sealed battery, so I set the regulation point at 14.2 VDC. At this voltage, less than 10 mA is flowing into the battery.





I provided the regulator with a blocking diode to prevent discharge into the regulator when a power source is not present. This blocking diode also isolates the portable power system's battery from charging sources when the regulator is defeated by switch S1. All resistors in the regulator were ¼ watt. I used a 5 Amp blocking diode even though it only handles 1 Amp. The additional mass of this heavy diode acts as its heatsink with the regulator's sealed enclosure. Use a clip on heatsink on the LM 317T. I used a plastic enclosure with a sheet metal face, 6 inches long by 3.75 inches wide and 2 inches deep (Radio Shack #270-627 for $2.79). The circuit went together on a small two inch by three inch piece of perf board mounted inside the enclosure.

The Case

When I first got the PowerBook, I went shopping for a case and didn't buy one. All the cases I could find were modeled on Yuppie luggage concepts. I wasn't going to pay over $150 for a cloth case that wouldn't protect the PowerBook against water, dust, or impact.

Then I remembered the Pelican plastic case that Juan Livingstone used to house the video gear on our trip to Colombia. This case was so air tight that we'd have to activate the air vent in order to open the case when we lost altitude. These cases are unbreakable, watertight, and dustproof. They carry a lifetime guarantee that only specifically excludes shark bite, bear attack, and children under five.

I used the Pelican Pro Case model 1550. It measures 20.5 inches long by 16.75 inches wide by 8.5 inches deep — about the size of a large briefcase. These cases are available at most big camera stores and this one cost $115. I looked long and hard at the next smaller size, but it was too small to contain all the power system equipment and the PowerBook. The 1550 case is heavy (about 12 pounds), but after seeing the routine abuse heaped on our equipment in Colombia, I figured that the case was the last place to save weight.

I had originally planned to attach the Solarex MSX-10 Lite to the outside of the case. After some thought I decided to stow the PV module inside the case instead. If the module is mounted on the outside of the case, then the case and its contents must be placed in the sun. I more fancied sitting under a tree with the case, the computer and everything else, and placing just the module out in the sun. I am loathe to drill holes in this wonderfully watertight case. I also wonder about PV module damage if it is permanently attached to the case's exterior.

As I finally set up this system, everything stows within the case and is capable of the most extreme travel imaginable. The Pelican case came with two "pluck & chuck" foam inserts that allowed me to nestle each component in its own snug foam pocket. The degree of protection offered to both the system components and the appliances in the case is excellent. This system will bounce down a rutted road in the back of a truck. It can take being dunked in a mountain stream. No matter how rough the going gets, this system and its loads will arrive undamaged and ready to go to work.

The Inverter

The inverter allows use of an appliance's stock power supply. In order to recharge the PowerBook, or Amateur radios, I simply plug their standard power supplies into the inverter's 120 vac power. I tried three different inverters in this system, a PowerStar POW200, a Statpower 100, and the new PowerStar Pocket Socket (100 watt). All performed equally well when powering the loads. The new PowerStar Pocket Socket smallest 100 watt inverter I have ever seen and is perfectly sized for this system. The larger Statpower model while heavier had a lower idle current (50 mA for the Statpower versus 175 mA for the Pocket Socket).

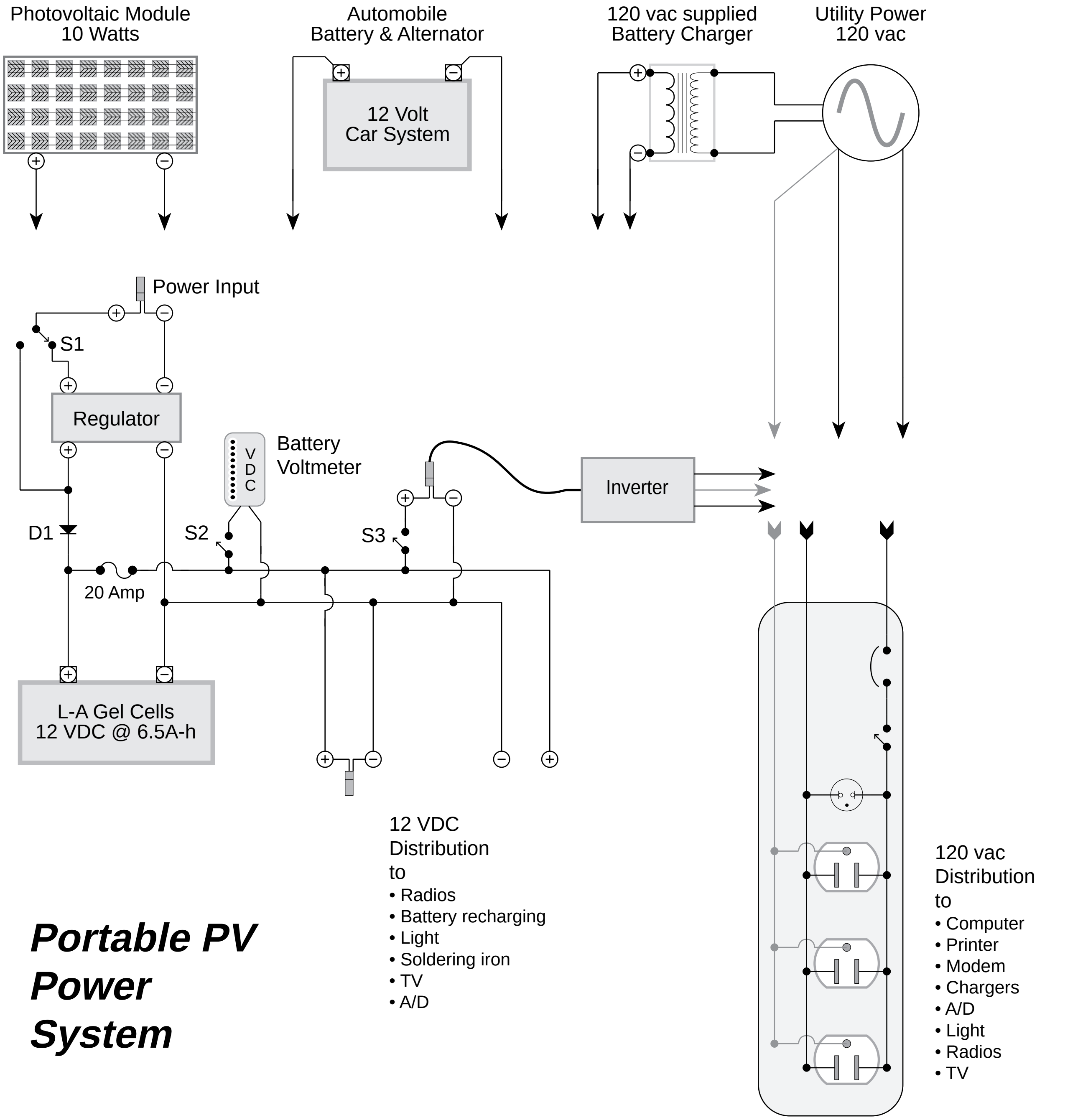
While operating the PowerBook on the system, the inverter consumes about 1.1 Amperes of current. With the PowerBook sleeping and recharging its battery, the inverter consumes about 400 milliAmps of current. Any of the inverters mentioned above still has lots of snort leftover to recharge radio batteries, run a small printer (like a 26 watt Hewlett Packard DeskWriter/Jet), or even power some compact fluorescent lights. While the inverter may seem oversized for this tiny system, there is a method in my madness.

The inverter allows this portable system to be more opportunistic. In my experience, much back country travel is by car or truck. The 100 watt inverter allows this miniPV system to mooch power from a vehicle. Loads being powered by the system's tiny internal battery can be transferred to the vehicle's battery while it is available.

The Battery

I used a Panasonic model LCR12V6.5P sealed lead-acid, "gel cell" battery. It has a rated capacity of 6.5 Ampere-hours at 12 VDC. It weighs in at 4.8 pounds and is the heaviest component of the system, except the PowerBook. Its dimensions are 5.95 inches long by 2.54 inches wide by 3.70 inches high. This battery cost $32 from Digi-Key (800-344-4539), and is widely available.

I would have liked to carry more battery capacity in this system, but its size and weight had reached the limits of



Portable PV Power System

portability. If the system were any larger, it would not be carry-on luggage on an airliner. Considering its value, this system rides in the cabin with me.

Increasing the battery's capacity without increasing its size or weight is a problem. I looked at many battery technologies for use in this system. I settled for what I described. In the future either rechargeable lithium or nickel-metal hydride cells may offer more energy for the weight, but they were simply too expensive for me to use. I look forward to upgrading the battery and thereby the entire system's performance in the future.

Instrumentation

I included a SunAmp LED bar graph voltmeter in the system. It is small, lightweight, and very rugged. Current consumption is a low 20 mA, but I still turn off the meter when I don't need it. The range of this LED voltmeter exactly suits the lead-acid gel cell battery. I cannot conceive of operating a portable system without knowing at least the system's voltage.

Plugs, Connectors, and Cords

While problems of weight and size plagued me, the real battle was connectors and plugs. Originally I planned to assassinate all the plugs and connectors and solder all the connections. Then I realized that this vastly limited the system's possible configurations. In the end I succumbed to standard 120 vac plugs and cigar lighter plugs and sockets for the 12 VDC gear. Here are the reasons why.

I am no lover of the cigar lighter plugs. The are bulky, and for their size offer tenuous high resistance connections. But I wanted the system to be flexible, and most cars come with a cigar lighter, so when in Rome….

I fitted the Solarex PV module with a male cigar lighter plug (the Sovonics module already was so equipped). I attached a male cigar lighter plug to my 120 vac wall cube battery recharger's output. I made a cigar male to cigar male fused jumper cable to interface with a vehicle's system. The power input to and output from the system is via cigar lighter female plugs. Two cigar lighter "Y" cables (one male into two females) are included in the case. These cigar "Y"s allow use of two charge sources or two DC loads.

Portable PV System Cost

Component	*Type*	*Cost*	*%*
PV Module	Solarex MSX-10	$130	28.1%
Case	Pelican 1550	$115	24.9%
Inverter	Modified Sine ≈100 watt	$100	21.6%
Battery	Panasonic LCR12V6.5P	$33	7.1%
Voltmeter	SunAmp BCM	$30	6.5%
Plugs	Cigar M/F	$16	3.5%
Battery Charger	120 vac/16 VDC	$15	3.2%
Regulator	Homebrew 1.5 Amp.	$8	1.7%
Plugstrip	any ole' type	$7	1.5%
Extension Cords	16/2 lightweight 120 vac	$6	1.3%
Wire	14 ga. and 22 ga.	$2	0.4%
	Total	$462	

The use of cigar lighter receptacles allows high flexibility. For example, in a vehicle I can plug the inverter directly into the car battery, run the powerbook from the inverter, and use the 120 vac power supply to recharge the portable system's gel cell battery. The use of standard connectors everywhere allows system components to serve outside of the system. For example, the PV module can easily recharge a dead car battery.

The system also stows several cords inside the case. Both PV modules have 12 foot extension cords that allow them good access to the sun. There are two 12 foot, 120 vac extension cords to bring in grid power and distribute inverter produced 120 vac.

System Cost
Well, it cost more than I thought when I began this project. Considering the portability, and utility of the system and its loads, I think the cost is justified. The damages are detailed here.

System Performance and Operation
While the internal PowerBook battery allows two hours of operation, this system extends that time to seven hours with no energy input. If a the Solarex MSX-10 Lite PV module is in the sun, then operating time is increased to twelve hours. If the Sovonics module is also deployed, then operating time is about 15 hours.

Since the PV modules are portable, they can be repositioned during the day to capture the maximum amount of sunlight. Using such manual tracking, this system will recharge in a single day with both modules deployed. Recharging via the 120 vac supply is accomplished in about 14 hours. I have recharged the system from a vehicle battery in as little as six hours.

Conclusions
The only true advantage of portable computers and communications devices like the ICOM handytalkie is in the freedom of movement they offer. A system like this one allows us to transport and use these electric tools in very remote places. And we can remain in places without power and still have the use of these electric tools.

Access
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