
BACKPACK
Electricity

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Backpack Electricity

Electricity. Our world and our lives have become dependent on it. There is little we do in our modern, technological society, which doesn't involve electricity anymore. We use it in our homes, offices, stores and even our cars. Without it, our world, as we know it, would come to an end.

Yet, that happens to countless people every year... at least for short periods of time. The reality is that our electric grid is extremely susceptible to damage, as well as outright attack. Pretty much every major storm, whether an ice storm or a hurricane, causes power lines to go down, requiring quick work on the part of countless repair crews who are always on standby. It's not uncommon for the damage to be greater than the capacity of those crews and for it to require days before that work is completed.

Actually, according to statistics kept by the Department of Energy (DOE), our nation's incidence of blackouts is on the rise. We currently rank number one in the world, of all advanced nations, for blackouts lasting more than one hour. That's not the kind of distinction we want to be known for.

When Hurricane Katrina hit the Gulf Coast, some of the residents around the New Orleans area were without electricity for as long as six weeks after the hurricane. That meant that they didn't have phone service, they couldn't use their refrigerators, their heating and cooling systems didn't work, and you can forget about things like watching the ball game or getting on the Internet. In fact, the stores were closed, because none of their computerized cash register systems worked.

People were struggling to survive during those six weeks, because of how much was shut down due to the loss of electrical power. Those who were trying to survive in the city were literally digging through dumpsters, in order to find something to eat.

If that's what happened in a regional event, what would happen in a major event, something that disrupted power for the whole country or even for a majority of the country? Clearly, the loss of electrical power over a wide area, such as that which could be caused by an EMP, would be devastating.

The truth is, our electrical grid is aging and in need of massive repairs. When the power plants, sub-stations and lines were designed and built, it was with an intended lifespan of 50 years. Well, many of the power plants are surpassing that age and we have some electrical transmission lines which are over 100 years old... and are still in use. This has caused the American Society of Civil Engineers to give our nation a D+ in their latest Infrastructure Report Card.

Of the estimated 3.6 trillion dollars that needs to be spent on bringing our infrastructure up to par, a full trillion is required just for the electrical grid. That's just to bring it up from a D+ to a C; I have no idea what it would cost to bring it up to a B. Since the money basically doesn't exist for that, we can expect to see continued problems with the grid, as well as continued blackouts.

But that's not all. Our country has enemies and there are ways that those enemies can attack our electrical grid directly. We're not talking little attacks either. If these attacks happened, they will either affect the whole country or at least large parts of it. Specifically, enemies could attack our grid via:

- Cyber-warfare - This has already happened in the Ukraine and Africa, where electric power was taken out for entire regions by hacking into the computers controlling power plants or the sub-stations. Both China and Russia have invested heavily in the ability to penetrate and attack everything from our financial systems to government systems, with the power grid somewhere in between. Our electric grid receives an average of one cyber-attack per day, mostly just to test out our defenses.
- Direct terrorist attack - There are nine critical sub-stations in the country, which if taken out, would disable the entire grid for a year. While the actual sub-stations in question are a very closely guarded

secret, the very fact that it can be done is common knowledge. A sub-station in San Jose, California was taken out by sniper fire in 2013. This was seen by many as a live-fire test for future terrorist attacks.

- EMP (electro-magnetic pulse) - Perhaps the most serious attack against our electric grid would be by a high-altitude EMP, created by exploding a nuclear bomb above the atmosphere. From 300 miles up, a small nuclear bomb exploded over the central United States would create a serious enough EMP to destroy electronics and the grid nationwide.

There have been countless warnings that a major disaster is going to strike our electrical grid. The report by the EMP Commission has some rather scary conclusions, especially the one about 90% of our population dying of starvation, before full repairs can be made to the grid. But there are others too, including a report by the head of the NSA, which came out just as I was starting to write this book.

According to General Keith Alexander, the head of NSA and the US Cyber Command, we should be expecting an increased number of successful cyber-attacks against our grid. These will be perpetrated by enemy governments, terrorists and hackers, breaking into the control systems for power plants and electrical distribution on the grid and shutting down systems. While many of these will undoubtedly be easy to repair, people will be without electricity while those repairs are being carried out.

Should a foreign power or terrorist organization decide to make direct attacks against our grid at the same time that these cyber-attacks are occurring, it could leave large parts of the country without power. The larger such attacks became, the more difficult it would be to accomplish repairs and the thinner the workforce responsible for making those repairs would be spread.

The thing is, there are way too many things that can bring down the electric grid, either for short-term or long, either regionally or nationally. Considering our national dependence on electricity, that makes electrical power production a necessary part of anyone's survival plans.

Of course, it's possible to live without electric power; our ancestors did so for millennia. But they had ways of doing things that we've forgotten. They were also much hardier people, accustomed to doing hard physical work and putting up with hardship in their lives. We, on the other hand, are accustomed to having electrically powered devices for everything from cooking our food to building our homes. Few of us actually have the physical strength and stamina needed to do things the ways our ancestors did.

While survival without electricity is possible, it's much easier to survive with electrical power. There are just too many things we all own, which make our lives easier. Considering that survival is much harder than normal life anyway, anything that we can do to make it easier is well worth doing. Just a few electric appliances and tools could literally make the difference between life and death.

Besides that, most of us keep our survival library on our smart phones or tablets. Few actually have all that information printed out, in a way that it is convenient to use. We are so accustomed to using our electronics for everything from communications to dealing with boredom, that cutting them out of our lives might actually be counterproductive. Maintaining ready access to the world of information we store on them is well worth placing high up on our list of survival priorities.

This may sound a little strange from a traditional survival mentality, and to be honest with you, it was to me at first, but then I started finding ways of using my handheld electronic devices as survival tools. That changed my tune.

Granted, keeping a cell phone working won't help you survive as well as making sure that you have a fire burning to provide you with heat or that you have purified water to drink; but it can help make sure that you have the information you need to create those things available to you. In that sense, hand-held electronic devices and the electrical power to operate them can quickly become an essential part of anyone's survival plan.

But having electrical power goes farther than that. Regardless of the disaster we face, one thing we all want to do is return things to some level of normalcy. That means having the ability to reestablish the lifestyle that we had, before the disaster struck. Sometimes this is impossible and we are forced to create a "new normal" to replace the old normal. That happened to many of the people who lived in New Orleans before Hurricane Katrina struck. It also happened to many of the residents of Sukuiso, Japan, after the tsunami destroyed the Fukushima Daiichi Nuclear Power Plant in 2011.

Without at least some electrical power, it is virtually impossible to restore our lives to anything close to what we consider normal. So, the ability to generate electrical power is an important part of restoring normalcy to your lives. Even though we can create a new life without it, we can't create the life we now know; and why should we?

Human knowledge has grown by leaps and bounds. They say that the sum of human knowledge now doubles every 22 months. A lot of that has been made possible by the technology we have created; technology that is powered by electricity. The loss of all that knowledge, forcing us to go back to a lifestyle lived in the 1800s, would be catastrophic. Better to retain what we can, even if we can't use every bit of it immediately after the disaster strikes.

FITTING ELECTRICAL POWER GENERATION INTO YOUR SURVIVAL PLANS

Most of the prepping and survival community has developed multiple plans to choose from. Depending on the disaster, the severity of the disaster and how other people react to that disaster, we will either bug in or bug out, seeking to put ourselves in a position where we will have the greatest possibility of survival.

Really, that's the only thing that makes sense. Relying on a single "one size fits all" survival plan is foolish, especially when we don't know what sorts of disasters we are going to be confronted by. Nor can we accurately predict what others are going to do. Considering that man is the most dangerous predator on the face of the Earth, our plans have to take into consideration what others do.

Yeah, I know, you've got your guns and you can protect yourself. But I have to ask, against how many? Protecting your home and family against one or two thugs is one thing, protecting it against a hungry mob of 50 is totally different. And how many of those attacks will you have to survive, if people are starving and the word gets around that you have food?

In such a situation, the truth won't matter. Whatever you have will be multiplied in the retelling. Homes will be invaded and ransacked for ten pounds of food. When that is happening, do you really think you can keep it a secret that you're eating well? Is your OPSEC really that good? Are you sure your neighbors haven't seen you unloading your truck sometime or haven't looked over the back fence to see your garden and chicken coop?

As much as I believe that it is usually better to bug in than bug out, one of my triggers for bugging out is when it becomes clearly dangerous to stay at home. Yeah, I'm ready to fight off an attack; but I'm not foolish enough to think that I can fight off one every day, without someone managing to get me in the crosshairs of their hunting rifle. When that happens, the game is over.

So, the trick is to bug out before that time comes. That means reading the situation and keeping myself and my family ready to move. But there's a problem with that. That is the idea of leaving everything behind. Ideally, I want to be able to take as much with me as possible, especially the items which will help my family and I to establish a fairly comfortable lifestyle wherever we go.

For both bugging in and bugging out, I believe that electrical generation is important. While I'm at home, I can count on the electrical generation capability that I've built. But what about when I leave? If I had a prepared survival shelter in the woods, I'd want to give it the capability of electrical power generation too, just like my home. But that costs money, and since I don't have enough money to buy that cabin in the woods, I certainly can't set up solar panels on the roof and a wind turbine in the trees.

So, whatever power option I take with me on a bug out, has to be something that's portable; there's really no other option. Not only does it need to be portable, but it has to be man portable. That's a whole lot more difficult than making it vehicle portable. If all I needed was vehicle portable, I could mount solar panels on the camper shell on my pickup and call it good. But that's not good enough.

Of course, by making it truly portable, I give myself the option of using it wherever I go or whatever I do. The same unit that I take on the bug out can be used at home too. If I buy a camper trailer or a sailboat, I could carry it along there as well. No matter where I go or how I go there, I could take a portable power unit along. Almost sounds like I'm dreaming, right?

WHERE DID BACKPACK ELECTRICITY COME FROM?

That's when I started looking for a portable power generator. My first requirement was that it be portable; but I had already defined portable as man-portable, not vehicle portable. I also wanted something that would work no matter where I was. In other words, I didn't want my plans to be limited by whatever power generator I came up with.

What most people refer to as a portable generator is a gasoline generator on wheels. While the generator itself might be portable, I'm not so sure that the fuel for it is. I guess if all you're doing is going to a construction site where you need electricity, a gasoline generator on wheels can be considered portable. But there's no practical way of taking enough fuel along on a bug out to keep that generator running. So, for my needs, those aren't portable at all.

That left two options, solar power or wind power. While I like wind power, those units aren't really all that portable either. I suppose one could be brought along in pieces and assembled on site, but that kind of defeats the purpose of portability being mobile. The time it would take to assemble and erect a wind turbine makes it impractical as a portable unit. So now, all we have is solar.

I started looking around for a portable solar generator and found a few. But to be honest, I didn't like the price tag. Granted, solar power is expensive and has always been expensive. That's why we don't have more of our power production coming from solar. But there's just something about paying enough for a portable power generator to more than make a couple of payments on my house that just bothered me. It should be possible to do it cheaper.

Being the do-it-yourselfer type, I decided to look into building my own solar power generator... and you know something? It is cheaper. Not only do you save about half the price of buying commercial solar panels, but by eliminating the expensive custom case that those other units come in, you save another bundle of money. Ultimately, you end up with what you need, at a fraction of the cost.

So, that's what I'm going to show you; how to build your own. Actually, I'm going to show you several different ways of building your own. We're going to start with the simplest system I could build and then add to that, upgrading it. That way, you can decide what you want to build. There's no way that I can tell you what you need or what your budget can handle, only you can do that. So, I'm not even going to try. I'll lay out all the options and leave it up to you to decide.

I'm also going to give you the option to use this system as a base for your home emergency power system. What we're going to do can be used as the base for that system, simply by expanding on the power generation and power storage parts of the system. That way, you can have emergency power at home, as well as when you bug out.

The good thing is, none of this is really all that hard to do. If you're fairly good at making things, then you can make this system. I'll show you what you need and how to do it. I'll even show you how to get by without a few expensive tools, so that you don't have to spend a lot of money on tools that you might not use again. Just because I tend to collect tools doesn't mean everyone does and I don't want to push you to have to buy tools that you don't need.

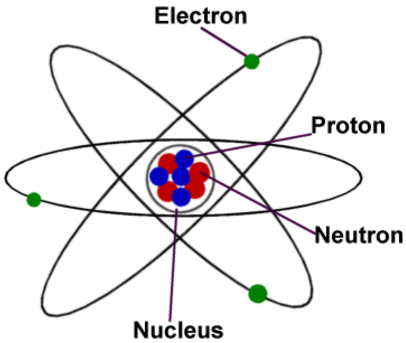
I'm also going to give you complete parts lists and show you what I paid for those parts. You may be able to find them cheaper than I did, but being the cheap sort, I tried to get them as cheap as I could. As such, eBay is one of my favorite sources of supply. For things I couldn't find on eBay, I'll tell you where I got the best price.

All in all, this is a great project that you can easily do on your own. Now, that doesn't mean the same as quickly. I'll warn you now that working with solar cells is a slow, tedious process. So don't think that you'll be able to do it in a day. You've got to take your time with the solar cells or you'll end up breaking them. Solar cells are made of paper-thin glass and as you can easily imagine, they break quite easily. So, care is needed in building this power generator, or you're going to waste a lot of money on things that you just throw in the trash.

Some Basics of Electronics

Okay, if we're going to build an electrical power generation system, it would help to have a bit of understanding of the electronics we're working on. While I suppose it's possible to build this project without any understanding whatsoever, just following the directions, I think it would work better for you to understand why you're doing what you're doing. Besides, if something goes wrong, you're going to need to understand how it works, in order to fix it. [1]

To start with, let's go back to high school chemistry. We all learned that atoms consist of three distinct particles: protons, neutrons and electrons. Protons, which are positively charged, and neutrons (no charge) are in the nucleus of the atom, while the electrons orbited the nucleus in layers.



The electrons are the part we're interested in, as they can move from atom to atom. This is how atoms bond together to form molecules, but it is also how electricity moves. Quite simply, electricity is the movement of electrons from atom to atom. We tap into the energy of that movement and use the electricity to operate a wide variety of devices. So, when we generate electricity, what we're really doing is getting those electrons moving.

Okay, so we need to understand a bit about how they move and how we measure that. To start with, electrons can either move all in one direction or they can move back and forth. We call moving in one direction Direct Current (DC) and back and forth Alternating Current (AC). Anything that is battery operated runs off of DC and anything that you have to plug in to an outlet in your home runs off of AC.

[1] For those who already understand electronics, this explanation may seem simplistic. That's intentional. I'm trying to give the readers the information they need, so that they can work with it, not make them electronic technicians.

The generator we are going to create creates electricity in DC. So we will have that to work with. But we are also going to convert it to AC, so that it can be used with your home's appliances.

We measure and define the electrical power produced or available from a source in volts or voltage. This measurement is the difference between the voltage and ground (which is zero), referred to as the electricity's "potential." When we are talking about ground, it is literally the electrical potential of the earth under our feet. Everything compares to that. You could call this the "strength" of the electricity, for a rough comparison.

Strength is a good term, because the higher the voltage, the more force it can generate when used, especially when used in electronic devices with motors. If you compare a battery-operated drill that uses a 12 volt battery to one which uses an 18 volt battery, you'll find that the one with the higher voltage battery produces more torque. So, higher voltages really are stronger... at least in some cases.

It is possible to have AC voltage and DC voltage. Devices are designed to work off of one or the other, not both. They are also designed to work off of a specific voltage. If too little voltage is provided, then the device won't operate. If too much voltage is provided, it will usually destroy the electronic device. However, it takes quite a bit too much to destroy devices, 20% extra voltage probably won't destroy it, 100% probably will.

Take a simple light bulb, for example; the kind you find in a flashlight. If you put a bulb designed for a two-cell flashlight into a flashlight with four batteries, the bulb will burn out immediately. But if you do the opposite, putting the bulb designed for the four battery flashlight into a flashlight with two batteries, it will barely glow at all. By the way, when the bulbs are in the right flashlights, the one with four batteries produces a much brighter light, another example of how more voltage equals more strength.

Another way we measure electricity is by its consumption. As we use electricity, it gets used up. Unfortunately, there is no such thing as a perpetual motion machine, nor is there any such thing as a perpetual electrical source.

Electrical consumption is measured in watts. There's a technical definition for this, but I'm trying to simplify things here. If we are working from a fixed capacity electrical source, such as a battery, every watt of power we consume, means that there is one less watt of power left in the battery. Eventually, the battery runs out of electricity and we have to either recharge it or throw it away.

BATTERY POWER

Since batteries are our most common source of DC electricity, we're going to talk about them for a moment. A typical battery, such as an AA battery, produces 1.5 volts of DC electricity. However, most devices that run off of AA batteries actually only use 1.225 volts of power for every battery that is used. That is an intentional part of the design, as the battery's voltage drops as the power in it is consumed.

Alkaline AA batteries contain 2.6 watt hours of power. That means that we can take 1 watt of power from that battery for 2.6 hours, or we can take 2 watts of power for half the time, 1.3 hours. After that time, the voltage that the battery can produce will have dropped below 1.225 volts, and the battery will no longer be able to power the device.

Of course, different types of batteries provide different voltages and can hold a different amount of power. Automotive batteries produce 12 volts of power and have a huge amount of it stored, by comparison to our little AA battery. The material makes a difference too, as that AA alkaline battery holds 2.6 watt-hours of power, but an AA carbon-zinc battery (the old "heavy duty" battery) only holds 0.65 watt-hours of power. In rechargeable AA batteries, nickel-cadmium (NI-CD or NiCad) contains 1.20 watt-hours, nickel-metal hydride (NiMH) contains 2.52 watt-hours and the newer Lithium-Ion (LI-ON) carries a whopping 3.1 watt-hours of power.

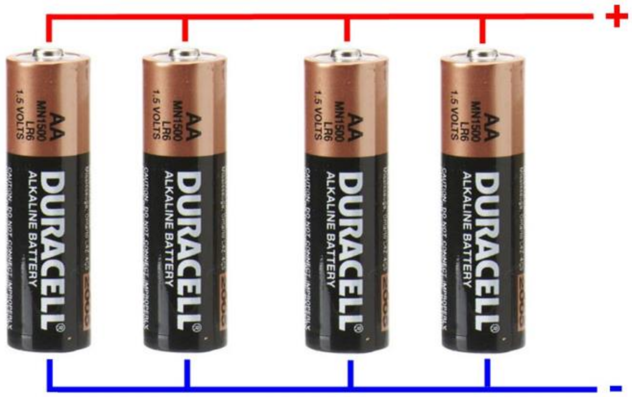
But what if we need more voltage out of a battery or we need more wattage than it can provide? That's why many devices use multiple batteries. We can string the batteries together in such a way as to produce more voltage or to produce more wattage. It all depends on how we connect them.

The first way to connect batteries is "in series." This means that the positive pole of one battery is connected to the negative pole on the next battery, just like you put them in a flashlight. This is the most common way of connecting batteries together.

Whenever batteries are connected together like this, we add the voltage of the batteries together; but the available power stays the same. So in the flashlight above, if those were three AA batteries (they're not), which produce 1.5 volts each, the total voltage would be 4.5 volts.

That higher voltage potential is stronger, able to accomplish more than 1.5 volts can. In two comparable flashlights, which use incandescent bulbs, the one with more batteries producing a higher voltage will produce more light. In cordless power tools, which run off of batteries, the ones with higher voltage battery packs (which means there are more batteries inside) produce more torque (more mechanical power).

The other way we can connect batteries together is in parallel. In this configuration, the positive pole of all the batteries is connected together by wires and the negative pole of all the batteries is connected together by wires.



In this case, the output power of the batteries stays at 1.5 volts, but the available power is added. So, since each battery is capable of producing 2.6 watt-hours of power, we have a total of 10.4 watt-hours of power now available.

There's another way of talking about the available power or the power flowing through a wire and that is in amps or amperes. Basically the difference is that watts talks about how much power is consumed, while amps talks about how much power flows through the wire. It is theoretically possible to have more electrical power flowing through a wire than is actually consumed, although that is rare. So, while the two are technically different, for our purposes, we can consider them to be essentially the same.

The reason I mention this is that some electrical devices will tell you how many watts of power they consume, while others will tell you how many amps of power they require. That can cause a lot of confusion, so we need to know how to convert from one to the other. The formulas we need are:

- To convert watts to amps, divide watts by voltage: W ÷ V = A
- To convert amps to watts, multiple the amps by the voltage: A x V = W

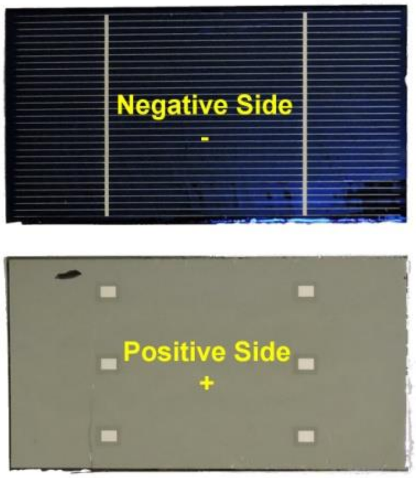
So, if you have a small refrigerator and the instructions say that it draws 5 amps at 120 volts AC, you can easily figure out that it will consume 600 watts of power; 5 x 120 = 600. This will become important when we get around to calculating the size of our power supply, as well as when we are trying to figure out what we can power with it.

One other little detail that I need to mention here is wire size. The more amps of power that is flowing through a wire, the larger the wire needs to be. If you try to draw too much electrical power through a wire, you'll end up heating up the wire and quite possibly melting it. At a minimum, you'll melt off the plastic insulation on the wire. Essentially, you'll be using that too small piece of wire as a fuse. The table below will tell you the maximum amount of current (power) in amps that you can use with different sized wires:

Wire Gauge (AWG)[2]	Max Amps for Chassis Wiring	Max Amps for Power Transmission
22	7	0.92
20	11	1.5
18	16	2.3
16	22	3.7
14	32	5.9
12	41	9.3
10	55	15
8	73	24
6	101	37
4	135	60
2	181	94

For the sake of what we are doing, you need to use the column for power transmission. The only time that the column for chassis wiring would be used is if you are building an electronic device and need to run power inside the device.

APPLYING THIS TO SOLAR CELLS



Okay, now let's take that knowledge and apply it to solar cells. Solar cells are actually quite similar to batteries. Both exist to produce electrical current and both have a positive and negative pole. While batteries produce electricity by chemical reaction, solar cells produce it by a photo-chemical one (that's light and chemicals). Like batteries, solar cells can also be connected together in the same way,

[2] The smaller the wire gauge size, the larger the wire.

either in parallel, adding their voltage or in series, adding their current. So, even though the voltage and current are different, the same laws apply.

The face side of a solar cell (the side that faces the sun) is blue, with white or silver lines going through it. This side is the negative pole. The gray or back side of the cell is the positive side. This distinction will be extremely important when we start connecting the solar cells together.

All solar cells, regardless of their size, produce 0.5 volts DC, just like AA, AAA, C and D cell batteries all produce 1.5 volts DC, even though they are different sizes. Also like those batteries, the difference that size makes is that larger cells produce more current (watts of power).

Although solar cells come in a variety of sizes, the two most common sizes are 3″ x 6″ and 6″ x 6″. We will be working with 3″ x 6″ solar cells, because the larger ones would force us to create panels that are too big to be portable. The 3″ x 6″ solar cells produce 1.8 watts of power each, whereas the 6″ x 6″ ones produce 4 to 4.2 watts. The larger size gives slightly more efficiency.

You may be wondering why I used watts, rather than watt-hours. The difference is that unlike batteries, solar cells don't have any capacity to store electrical power, only produce it. So, at any point in time, when the solar cell is receiving enough light, it will produce 1.8 watts. But the moment that the light is removed, it produces no power at all.

When building a solar system, these cells are connected together to make panels. Part of that is the manner in which we connect the individual cells together, just like connecting batteries together in a flashlight. 0.5 volts of power isn't going to do us much good, so we will need to connect the cells together in series to produce more.

That, of course, raises a question; how much power should we produce? On one hand, we could say that the amount of power which needs to be produced will depend on what the solar panel is going to be used for. After all, a cell phone will charge off a 5 volt DC USB connection, so we wouldn't need as much voltage to charge that cell phone as we would to charge a car battery. Nor would we need as much voltage to charge that cell phone as we would to run a home appliance.

There is a conventional voltage which has been established for solar panels, that's 18 volts. This means that we need to string 36 solar cells together in series, to create a string which will provide us with 18 volts. Where did 18 volts come from? It came from the fact that solar panels are normally used to charge 12 volt lead-acid batteries, and then that power is converted to whatever is needed to run the devices connected to the solar power system.

We need more than 12 volts in order to charge a 12 volt battery. So it's clear that the solar panels need to produce more than 12 volts. But it goes farther than that. The ratings on the individual cells, therefore on the panel, are based upon sunlight striking them from directly overhead. If the sunlight is partially blocked by cloud cover or if the sunlight is coming at an angle, such as during early morning and late evening hours, the efficiency of the solar cell is reduced. So, it might not produce a full 0.5 volts. The extra buffer in the design of the solar panels is to account for this and ensure that the solar panels are always producing enough to charge the 12 volt batteries.

Individual panels are then connected together in parallel to add the current (wattage) that they produce. For that matter, large panels can have more than one 36 cell string, with the separate strings connected together in parallel. That way, the panel produces more current. Since our panels need to be portable, we'll only have one string of 36 cells in each of them. But if you decide you want to build some big panels in the future, you could put multiple strings together in each panel.

POSSIBLE POWER SOURCES

We're talking about using solar power for our Backpack Electricity unit. But I want to take a moment out here, to talk about other means of producing electricity. While all these methods work, they aren't necessarily practical for our needs; especially our need for portability. However, you might want to consider some for home usage.

Since we are all accustomed to using electrical power for so much, it only makes sense to include some means of electrical power in our survival plans. While electrical power production isn't technically a requirement for survival, it will make things a whole lot easier. Many of the "conveniences" we use electrical power to run came into existence out of a need to make the basic tasks of life easier; especially when we look at the electrical conveniences we use around the home.

So, while we can survive without electricity, we can do so much easier if we have some means of producing it. Since there are many threats to our current source, public utilities, we should have a backup plan. The question then becomes, "What sort of backup power supply should we use?"

We're concentrating on solar power in this book, but that means that solar is our only option. Besides, we want to make sure that whatever we do, is something that makes sense. Therefore, it's only reasonable to look at the various options available to us, so that we can check to see that what we are planning on doing, truly makes sense.

Generators (fossil fuel)

The single most common means of producing electrical power is a gasoline or diesel generator. Generators are fairly inexpensive to buy, when you compare them to the other options available. They come in a wide variety of sizes, with capacities ranging everywhere from small enough to only power a few electric lights, to large enough to power a whole home.

On the surface, a "whole house" generator seems to be an excellent option, as it turns on automatically when electrical service is lost and can provide sufficient electrical power to run everything in your home. They are available in versions that run off of gasoline, diesel, propane and natural gas. However, those whole house generators consume a lot of fuel. So much, that they can run as much as $150 per day to operate.

This is the drawback to any generator, even the small ones. A portable generator that produces 4.5 kw of power, can easily burn five gallons of gasoline per day. That adds up quickly if you have a long-term power outage. So, while they are great for spot power, they are not cost-effective for long-term survival needs.

Solar Power

Solar has become the most popular form of "green" or "renewable" energy. While still a very small percentage of our nation's total power production, solar power has become the go-to solution, for people who want to get off the grid and produce their own. Most parts of the country have abundant sun to provide energy and once the panels are installed, they require no maintenance.

However, one solar panel doesn't produce a lot of power; you need a bunch of them. To date, they are still rather expensive; so if you want to have enough of them to power your home, you're looking at a rather large investment. I got a quote for putting enough solar panels on my home to provide my "average" usage, and the total cost was going to be $60,000. Needless to say, I didn't go through with it.

Nevertheless, solar is extremely popular. A lot of this is the fact that other than the purchase and installation costs, there is no cost whatsoever to operate the system. Payback on a typical installation is somewhere between 8 and 14 years. Once that payback is complete, you have free power for many years longer. This alone is enough to make solar power popular.

The lack of maintenance and ready availability of sunlight, no matter where you are, is what makes solar power so attractive for survival. A lot of the cost (roughly half) can be saved, by building your own solar panels and installing them yourself, rather than going with a turnkey system.

Wind Turbines

Wind is the second most popular form of green energy, as well as the second most popular for those who are going off-grid. Unlike solar, wind power does not work in all areas, but only those which have sufficient wind. Most require 10 mph of wind to operate, so they are most useful in areas where there is a lot of wind.

Overall, the cost of putting in wind power is less than that for solar. However, some municipalities have stiff regulations against them. Wind turbines tend to be noisy and neighbors complain about them for this reason. So if you live in the city, they may not be the best choice for you.

Another consideration is that they are not totally maintenance free. Bearings and generators can wear out, requiring replacement. So in a survival situation, some spare parts would be advisable.

Even with these drawbacks, wind produces enough power that it is a good alternative to solar. Some people put in both systems, so that they have some power production at night and during storms, when the solar panels aren't producing any electricity. On the flip side of that coin, the solar panels are likely to be producing power when the wind turbine is not.

Hydroelectric

Hydroelectric is a very efficient source of renewable energy, assuming that you have flowing water available to power it. As a renewable energy source, hydroelectric is hard to beat. Not only does it produce power efficiently, but it doesn't harm water supplies in the process. For this reason, hydroelectric power plants have produced about 3% of the nation's overall power usage for over a century.

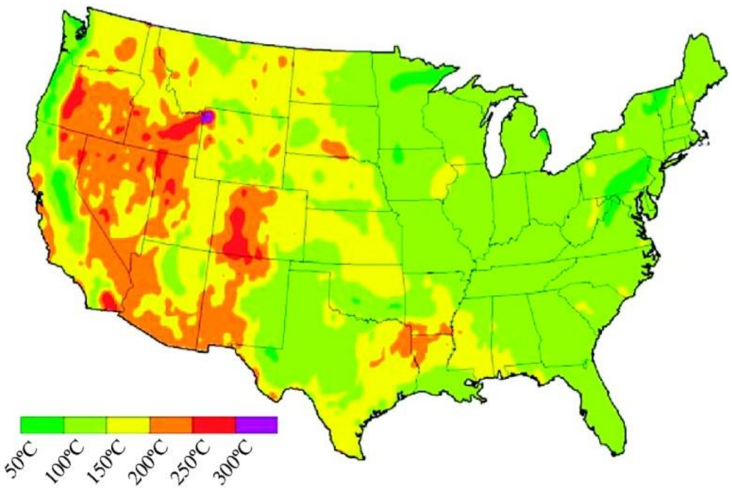
The reason that figure is so low is that it is difficult to find places where the hydroelectric dams which are needed for commercial power production can be installed. However, on a smaller scale, pretty much any flowing water source can be harnessed for electrical power production in small quantities. Just as our ancestors used water wheels for powering mills of all types, we too can harness water for our personal use.

The main requirement for using hydroelectric power to produce electricity is a water wheel. The output of the wheel is then run through a series of gears, speeding it up enough to turn a generator and produce electricity. This is a bit more complicated than either wind or solar power, but still quite doable... assuming you have a good source of water. Unfortunately, few people do.

Geothermal

Geothermal uses the Earth's heat, converting it to power. While it has been used more for heating homes than for electrical production, the technology does exist for making electricity from geothermal power.

Installing geothermal requires drilling a series of wells deep enough into the earth to tap into the heat there. This varies considerably from place to place, with the western part of the country being a much better location, with much easier access to the Earth's heat. Wells for tapping into geothermal power in the west do not have to be anywhere near as deep as those in the east.



Installing geothermal power is a rather complex task; not something you can do on your own. Each system has to be engineered and designed for the thermal conditions in the Earth's crust, at the particular location. This, along with the cost of drilling the wells, makes geothermal a very expensive option, even more expensive than solar.

What to Use?

As you can see, each method has its pros and cons. If you have a ready source of flowing water available, then hydroelectric is an ideal option for you. Be careful though, as you will probably need some sort of permit to make use of that water, even though it is on your property. You don't need the EPA slapping you with a huge fine after putting in your system.

Most people select solar or a combination of solar and wind power for their off-grid or survival power source. The nice thing about these systems, is that while they are both available commercially, you can also build them yourself. That saves you money and gives you the capability of customizing the system for your particular needs.

Rather than make a huge investment in solar panels for their home, what most people do is to buy a few at a time, as they can afford it. The money they then save on their energy bills is set aside for the purchase of more panels. In this way, they are able to build their system gradually, without a large outlay of cash or going into dept.

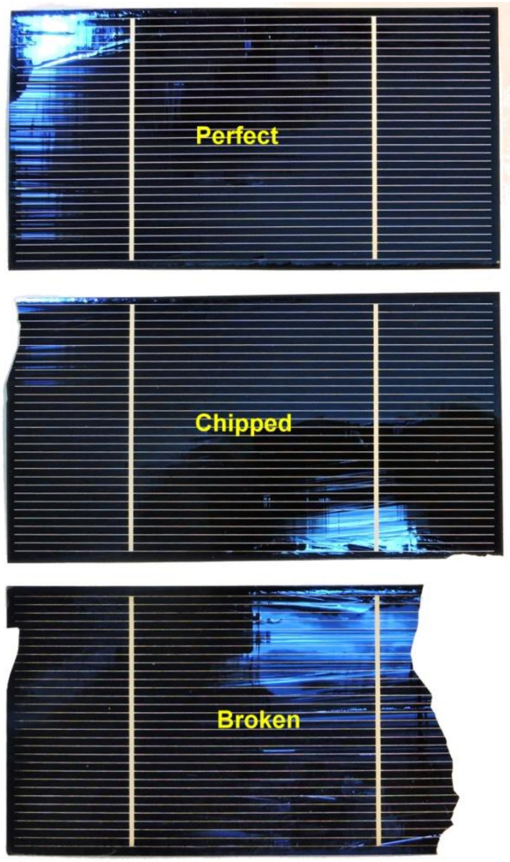
Of course, we're building a portable system, so we're only going with a few panels. Nevertheless, the system can be expanded, by adding more panels and more power storage. When expanded, it can be used to power some of your home, saving you on your monthly energy bills.

Building the Solar Panels

The first and hardest part of building our solar power generator is building the solar panels themselves. If you already know how to solder electronics, you're ahead on this part, as that's the biggest part of making solar panels. If you don't already know, don't worry, I'll show you how.

As we've already discussed, we're going to be making panels of 36 cells. There are two basic ways that this size panel can be made, in a 6 x 6 configuration or a 9 x 4. A 6 x 6 configuration gives you a panel that's roughly 38.375" x 20.375". Since 38" long is a bit long to be easy to carry, we're going to use a 9 x 4 configuration, which will end up with a panel that's about 32-3/16" x 26-5/8". That's closer to square, so it's easier to carry.

Solar cells can be purchased in three basic grades, either tabbed or untabbed. Tabbing refers to whether or not they already have lead wires soldered to them. Tabbed cells are easier to work with, but you will pay extra for them. We are going to use untabbed cells.



The three different grades refer to the physical condition of the cells at the time of purchase. As I previously mentioned, solar cells are extremely fragile. You can expect to have some loss from breakage, especially as you are getting used to working with them. Solar manufacturers have this problem as well, so not all their cells come out perfectly.

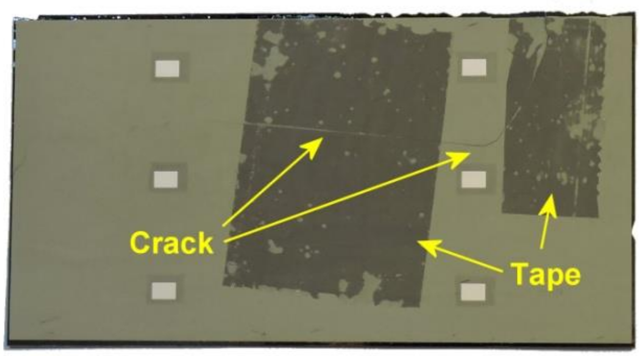
In the photo on the right, we see the difference between the three grades of cells. The Perfect or complete cells at the top have no missing pieces or cracks in them. These are the cells that are used by solar manufacturers in building their own panels for sale. As such, they are not as commonly available for purchase by the public. Perfect cells are the most expensive and really don't offer any practical advantage over chipped cells.

The vast majority of solar cells available for sale to the public (especially on eBay) are Chipped. As you can see in the photo, this refers to small chips on the edges. Some might be larger than the one shown, perhaps twice the size. The loss of this small surface area does not lower the voltage output of the cell at all and the loss in wattage is so minimal as to be virtually undetectable. For most people, this is the most economic choice, offering good quality at a reasonable price.

Broken cells can have large areas missing, as shown in the bottom cell in the photo. However, I have never seen broken cells that were so bad as to not have both vertical contact lines complete on the cell. These cells still work and still produce the same amount of voltage. However, the wattage of the cells is reduced proportionally to the surface area lost.

This loss of wattage is a bit deceptive, as it not only affects the broken cells, but all the cells in the string. Let's say that you are making a panel and you have half broken cells and half perfect cells. Of the broken cells, the worst one has lost 25% of the total surface area. That cell will be the limiting factor for the string. The most current that the panel can produce is 75% of the normal power for that size cells, even though the majority of the cells are in much better condition. For this reason, broken cells are not a good bargain, even though they are the cheapest.

Some cells might also be cracked. Depending on the crack, this could be devastating or it could be immaterial. The key is how the crack runs. The silver and white lines on the face side of the cell are the electrical contacts. The two larger lines are the ones we are going to solder the tabbing wire to. If a crack in a cell makes it so that there is a portion of the cell which does not have an



unbroken path to the electrical contacts, it is the same as a broken cell. But if there is a continuous path from all parts of the cell, to the electrical contacts, the cell will still produce full voltage and wattage.

In such a case, the solar cell can be repaired by the simple expedient of taping the back side of it. The solder pads on the back of the cell (six of them in the photo above) are also electrical contacts, so the tape cannot cover them. Use a tape that will not be easily affected by heat for the best results and remember that you get one chance. If you try to remove the tape, you'll break the cell.

If you follow the path of the crack in the photo above, you can see that it runs horizontally across the cell for a ways and then turns towards the top edge. This would normally seem to isolate the small section in the upper-right-hand part of the cell, making it as if that section of the cell were not there. However, in this particular solar cell, there are contact lines at the ends of the cell as well, so that portion of the cell still has a clear pathway to the electrical contacts.

SOLDERING ON THE TABBING WIRE

Most solar cell vendors sell their cells as a kit, providing everything you need electrically to make a complete panel or a number of panels. This includes a few extra cells, to make up for the inevitable cells that get broken in process. A one panel kit will include:

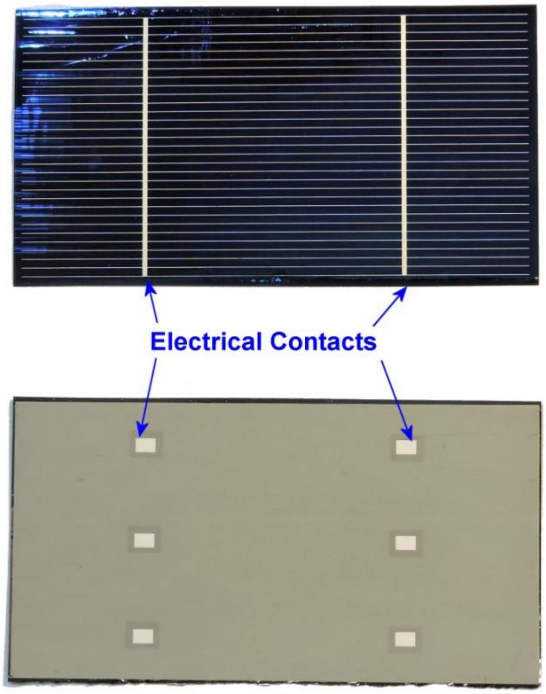
- 38 to 40 solar cells
- Tabbing wire
- Buss wire
- Flux pen

The solar cells will be stacked together and probably placed between two pieces of corrugated cardboard for protection. A rubber band will hold the cardboard together and heat shrinkable plastic wrap will be placed around it. Open the package carefully, as you can actually break a whole package at this point. [3]

In addition to what comes in the kit, you will need to have the following to make your solar cells into strings:

- Soldering iron
- Flux-cored electrical solder (Plumbing solder is acid cored and electrical solder is rosin cored; be sure to get the right solder. Acid cored solder will destroy electronic components.)
- Cardboard or paper to cover the work surface
- A yardstick or meter stick
- Wire cutters
- Masking tape
- A small weight (A large mechanic's socket works well)
- A soldering tool of the type used to hold components in place.

Before you can solder the tabbing wire to the cells, it needs to be cut. Tabbing wire is 2mm wide, very thin, uninsulated, flat copper wire. It is silver in color, because it is "tinned." This means that it is coated in solder to make it easier to solder to other parts.



The tabbing wire is cut to twice the width of the cells. Since we are using 3"x 6" cells, and the electrical contacts cross the 3" width, we'll need to cut the tabbing wire to 6 inch lengths. You need one per electrical contact on the face of the cells. This usually means two wires per cell, or 72 wires for a 36 cell panel. In addition, you'll need two extra pieces of tabbing wire per string, making our total 80 pieces of wire. Please note however, that if you buy solar cells with three

[3] A complete parts list is in the appendix.

electrical contacts, you'll need three pieces of tabbing wire per cell, instead of two.

If the tabbing wire is kinked from being folded around a piece of cardboard (rather than a spool) or curved from the wrapping process, it will need to be straightened. This is a soft copper wire, so it is easy to bend. It is easier to straighten all the pieces before starting soldering, than to have to straighten them in the midst of soldering.

Before soldering, it is important to put flux on the electrical contacts you are going to solder to. The flux is there to clean the surface, removing oxidation, so that the solder can stick to it. Flux pens contain a liquid flux, which is easier to use for small contacts spaces than a paste flux.

To get the flux flowing into the fibrous tip of the pen, push the pen point down onto the cardboard or paper covering on your work surface, compressing it back into the pen. You should be able to see the flux flow into the tip, changing its color.

Applying the flux to the solar cells requires nothing more than drawing on the cell, where you want the flux to go, as if you were drawing with a magic marker. A small amount of the flux will flow from the fibrous tip onto the cell. It is normal to do this just before soldering, rather than doing them all in advance.

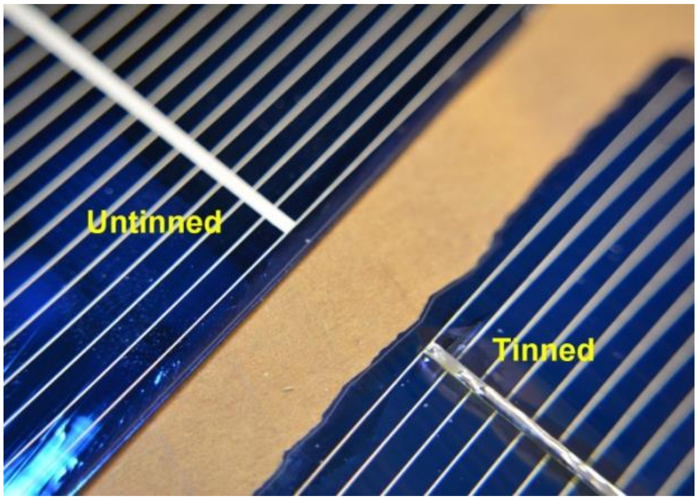
Technically, you don't need to tin (apply solder) to the electrical contacts on the solar cells, but can just use the solder that is already tinning the tabbing wire. However, my experience has been that when I do that, I end up with a number of cells where the tabbing wire does not attach to the entire electrical contact. Therefore, I tin the electrical contacts before soldering on the tabbing wire.

Soldering is a fairly simple operation. All you need to do is to heat the contact enough with the soldering iron, so that the contact will melt the solder. Solder is a tin and lead mixture, so it melts at a fairly low temperature. I use a temperature control soldering iron, set for 700 degrees for this operation.

The tip of the soldering iron must be clean and tinned with solder to work properly. To tin a new soldering iron or a new tip on a soldering iron, flux the tip and then wrap solder around it while it is cold. Then turn on or plug in the soldering iron and allow it to heat. The melting solder should stick to the freshly fluxed tip. Wipe the excess solder off on a wet sponge or steel wool.

Please note that other than tinning the tip, you don't want to melt the solder directly with the soldering iron, but rather use the soldering iron to heat the component that you want the solder to stick to. It doesn't matter if you're soldering a solar cell, splicing a wire or soldering electronic components to a circuit board, this rule is the same. The soldering iron shouldn't melt the solder, it should only heat the components, so that they are hot enough to melt the solder.

Failure to follow this one rule will create what is known as cold solder joints. What that means is that your soldering iron will melt the solder and it might stay in place, but it won't stick to the component, in this case, the solar cell. So, it will break off, leaving you without a connection.

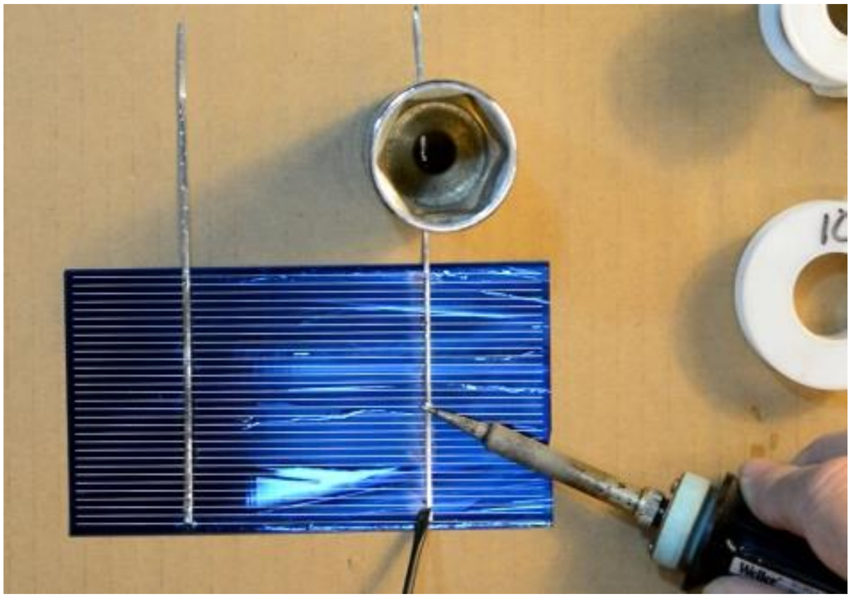


With solar cells, it's always easier to solder the face side of the cell first. So, we are going to tin the two contacts on the face side by running the soldering iron slowly down the contact, followed closely by the solder. Apply the minimum possible quantity of solder to the contact. It should be about like painting it on and should not end up lumpy. If you end up with too much solder on the contacts, simply go back over it with the soldering iron, melting and wiping off the excess solder.

With the two electrical contacts tinned, lay a piece of tabbing wire across the electrical contact on the face side of the solar cell. One end of the tabbing wire should be aligned with the end of the contact. Hold the extra tabbing wire down with a weight, to keep it in place.

Hold the other end of the tabbing wire in place on the solar cell with a soldering tool. Clean the tip of the soldering iron by wiping it on a wet sponge or steel wool and then apply it to the tabbing wire at the end of the electrical contact where the extra wire is. You should see the solder tinning the tabbing wire melt almost immediately. You'll be able to tell that it is melting, because it will become shiny, as if it was wet.

Slowly move the soldering iron along the length of the electrical contact, melting the solder so that it can attach to the solder on the solar cell. You'll have to watch the puddle of wet solder to know how fast you can move the iron.



Please note that as you move the soldering iron down the length of the wire, it will lose lots of heat to the wire. This will mean that the farther you go, the slower you'll have to move the iron. You can alleviate this a bit by putting just a touch of solder on the soldering iron tip, "wetting" it. Rather than touch the tip with the solder, I leave the solder accessible, with the end hanging in the air. Then, I can touch the end of the solder with the soldering iron tip to wet it.

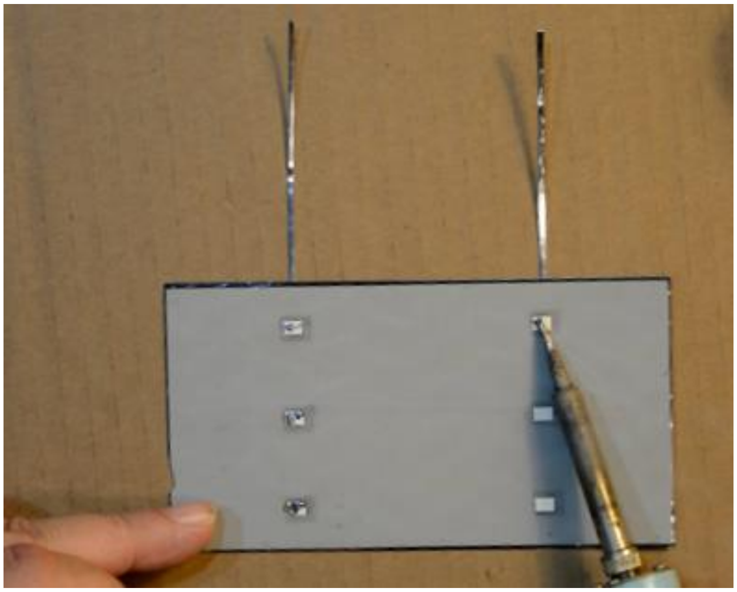
Once the tabbing wire is soldered to the solar cell, the solder will cool quickly, allowing you to remove your soldering tool and the weight immediately. Repeat this process for the other electrical contact on the solar cell.

All the cells need to have their tabbing wires soldered on, before you are ready to move on to the next step in the construction of your solar panel. This is a very tedious process and it is easy to get bored. I usually only solder tabbing wire on 10 or 12 cells at a time, then go off to do something else. That way, I don't get impatient and make mistakes.

The tabbed cells can be stacked; they don't need to be laid out separately. They are light enough that they will not break the cells beneath them. Just be sure to put them in a safe place, where nobody else will mess with them or place something on top of them.

PUTTING THE CELLS TOGETHER IN STRINGS

In order to turn our individual solar cells into usable strings, we're going to need to solder the tabbing wires that we just soldered to the negative or face side of the solar cells to the positive or back side of the next solar cell in the string. We started with the negative side, because it's much easier to bend the tabbing wire to align with the positive contacts, than it is to try to align it with the negative contacts.

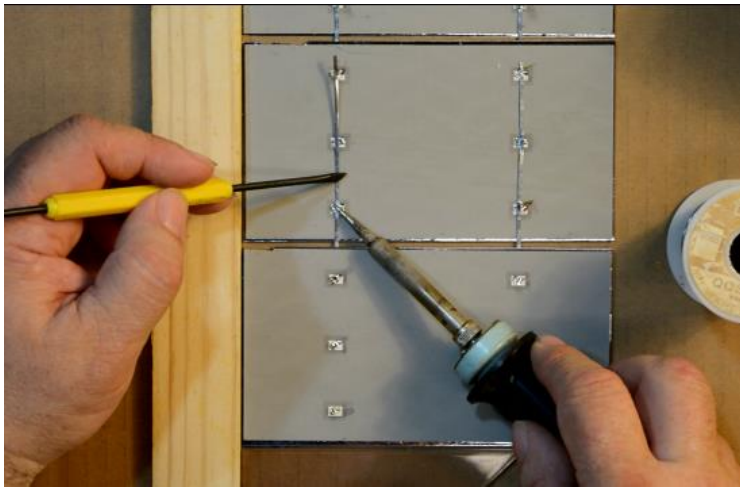


For the process of making strings, we're going to need to turn our solar cells face down, so that we can access the positive side of the cells. As we saw in the photo earlier, the positive electrical contacts are much smaller than the negative ones.

Like the negative contacts, the positive ones need to have flux applied and be tinned before attaching the tabbing wire. It is best to do this step on all of the cells, before trying to make the strings. As with tinning the negative electrical contacts, if you find that you have applied too much solder, simply melt it with the soldering iron and wipe it off. The solder will not stick to the rest of the cell, only the flux-coated contact pads.

It is important that the strings are straight, or they will require more space, making for bigger panels. So, tape a yardstick to your cardboard work surface, ensuring that it is attached firmly. This will give you a straight edge to align the individual cells with, in order to keep them straight.

Place the first solar cell face down on the cardboard or paper work surface, aligning its edge with the yardstick. Ensure that it is perpendicular to the yardstick and not crooked. The tabbing wires should extend from the side of the cell that's closest to the end of the yardstick.



Place the second solar cell face down, next to the first, so that its tabbing wires overlap the first one. There should only be 1/8" or less space between the two cells. The tabbing wire is flexible enough that it can bend up through this small gap and allow the two cells to be connected together. If both cells are perpendicular to the yardstick, the tabbing wires from the second should align with the positive electrical contacts on the first. Solder the tabbing wires to the contacts on the first cell, holding the wire in place with light pressure from your soldering tool.

Repeat this process, adding cells to the string, until you have 9 cells in the string.

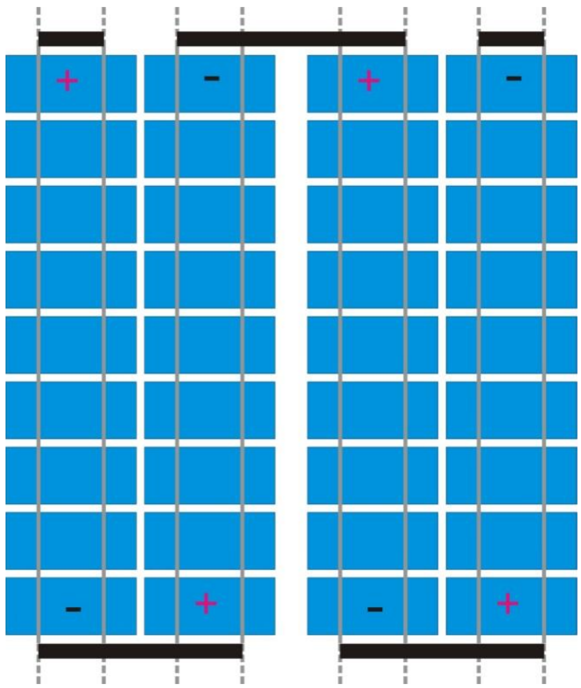
The last cell needs to have tabbing wires soldered to the positive electrical contacts on the back side of the cell. These will extend off the end of the string, allowing this string to be connected with others, when we put them together. You may want to use your small weight to hold these pieces of tabbing wire in place, while soldering them, just as you did when you were soldering the tabbing wire onto the face side of the cells.

You will need a total of four strings of nine cells for each panel that you make. So, repeat the process until you have enough strings for the total number of panels you are going to build.

Please note that other size panels can be made as well, larger than what we are making for this project. It is possible to use larger solar cells, or to attach several groups strings together in one panel. In this case, each group of strings would produce 18 volts, but then they would be wired together in parallel to make a larger wattage output. But for the purposes of this project, we are going with smaller panels to make them portable.

CONNECTING THE STRINGS TOGETHER

For the sake of our solar panels, we are working with strings that are nine cells long, even though we need 36 solar cells in the string to make 18 volts DC. This is simply an expedient to make the panels more portable and easier to work with. A single string of 3"x 6" solar cells, 36 cells long, would be nine and a half feet long, not very practical in any application.



Four stings of nine cells equals the 36 cells we need, so it works out the same way electrically. The important part of this is that we need to maintain the polarity of the strings of cells, so that the whole set ends up being in series.

To do this, we simply alternate the direction of every other string, ending up with something like this.

As you can see, the positive end of the leftmost string is at the top of the diagram, while the negative end of the second string is at the top. The grey lines are the tabbing wire that you've used to connect the strings together, and the wider black lines are the buss wire you will use to solder the strings together. In this manner, we make one long string, with the positive end at the upper left and the negative end at the upper right.

You can, of course, change the orientation, as long as you keep the circuit as a single serial line of solar cells. I made the mistake of reversing one of my strings in a panel once and ended up with a panel that only put out 9 volts, rather than 18. I had to break the cells in the bad string and replace the whole string.

Buss wire is similar to tabbing wire, with the exception that it is 5mm wide, rather than 2. This allows it to carry more current. While that is not a necessity at this point, it would be if you were connecting multiple strings together. The buss wire is soldered to the tabbing wire, connecting the various strings together. The dashed lines in the diagram are excess tabbing wire, which should be cut off, once the buss wire is soldered to the tabbing wire.

The other thing you should note from this diagram is that I left extra space between the second and third string. This is not absolutely necessary, but since this panel is intended to be portable, I am going to put a spacer between these two strings, so that the glazing cannot be pushed down to make contact with the solar cells and break them.

Okay, now that we have an understanding of what it is that we want to do, let's talk about how we're going to do it. To start with, you don't want to solder the strings together, until you have them mounted to something. Handling the soldered together strings, without breaking them, would be just about impossible.

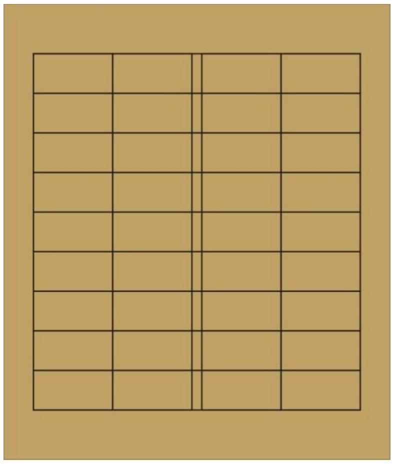
You'll need a backing board to attach the solar cells to. I'm using a piece of 1/4" thick luan plywood, often referred to as "underlayment." To make it waterproof, I've painted the back side of the board to make it water resistant. If you have it available, you might want to use some sort of plastic, rather than the plywood, to make it more water resistant. However, this will make the project somewhat more expensive.

The backing board needs to be cut to fit the overall size of the four strips of solar cells that will be attached to it. Measure your cells before making this calculation, as they may not be the exact size you expect.

	Width		Length
Cell size	4 x 6" = 24"		9 x 3-3/16" = 28-11/16"
Space between rows	4 x 1/8" = 1/2"		8 x 1/8" = 1"
Space for spacer	1 x 5/8" = 5/8"	Space for bus wires	2 x 1/2" = 1"
Frame	2 x 3/4" = 1-1/2"		2 x 3/4" = 1-1/2"
	26-5/8"	by	32-3/16"

In my case, my solar cells were 6" by 3-3/16", so I needed to make my panel 1-11/16" longer than I would have expected, if I had just based my work on nominal dimensions. Fortunately for me, I didn't trust my cells to be the exact size.

The other dimension that might change is the space left for the frame. I've left 3/4" all the way around, which is enough in most cases. However, if you use a commercial frame, or if you use 1" aluminum angle, rather than the C channel I am using, you may need to give yourself more of a border.



In addition, I've added 1/2" at each end of the panel for the buss wires to connect in. You might be able to get by with slightly less space, but I didn't want to take that chance.

Once you've cut your backing board to fit and painted the outer side (the inner side doesn't have to be painted, although I did, to prevent warping), you'll need to draw a rough layout for the cells, matching the dimensions we were just talking about, so that you can locate the strings correctly. When the cells are attached to the backing board, each will be in its own rectangle on that board. Please note that I've left a 5/8" space between strings two and three. [4]

The easiest way to connect the solar cells to the backing board is with silicone caulking. Place a small dab of caulking in the center of each block on your backing board, about the size of a dime, and lay the strings of cells onto it. Then, press the cells carefully in the center, to push them down into the caulking. Don't try to push them all the way to the backing board, but leave them floating about 1/16" above it. Allow the silicone caulking to dry overnight, before continuing.

Once the caulking has dried, you can solder the buss wire to the ends of the strings as I've shown in the diagram, and we discussed, above. You should not need any additional solder, as both wires are already tinned. Just heat them and press them together to get them to stick. Trim off excess buss wire and tabbing wire once the soldering is done.

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[4] An actual layout for this panel, with dimensions, can be found in the appendix.

You will also need to solder positive and negative wires to the ends of the string on the panel. These wires will need to pass out of the panel and allow you to connect the panel to the solar charge controller. I recommend using 14 or 16 gauge wire. A two-colored "zip cord" such as is commonly used for speaker wire will work well, as it will help you to identify which wire is positive and which is negative.

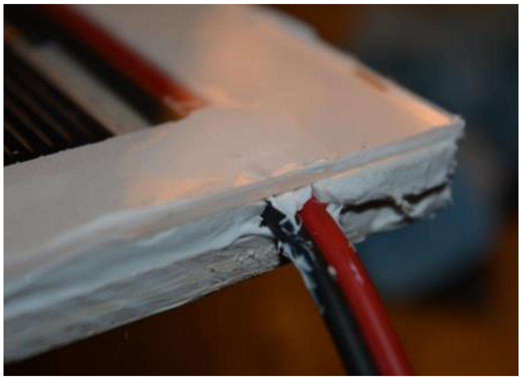
Important note: Some people add blocking and bypass diodes to their solar panels. These will not be necessary, as we are using a solar charge controller. If you were not using a solar charge controller, you would need to have blocking diodes on your solar panels, to prevent them from discharging the battery when there was not enough sun out for the panels to charge the battery (such as at night). The bypass diodes are used when a panel may be in the shade, so that it doesn't impede the operation of other panels wired in series with it. As we are not wiring the panels together in series, this is unnecessary.

Before going any farther, place the solar panel in the sun and check its output with a volt-meter or VOM. In direct sunlight, your panel should be producing 18 volts.

ASSEMBLING THE SOLAR PANEL

While the solar panel is working electrically, it is not really safe for use. That is, it's not safe for the panel. It can be damaged way too easily as it is. It needs to have a frame built around it, to protect it from weather and damage. We're going to build a frame, with glazing, onto the existing working panel.

While a number of different materials can be used for this, the most common is aluminum extrusions. There are commercial aluminum frames available for solar panels, but you can do just as well using aluminum C channel. Depending on what is available where you live, you can use 1/2", 5/8" or 3/4" C channel for your panel.



There are a number of different materials that can be used as glazing for a solar panel. While glass is probably the most common, glass is not very flexible. So it is probably not the best choice for a solar panel which is intended to be portable. Instead, we're going to use some sort of clear plastic.

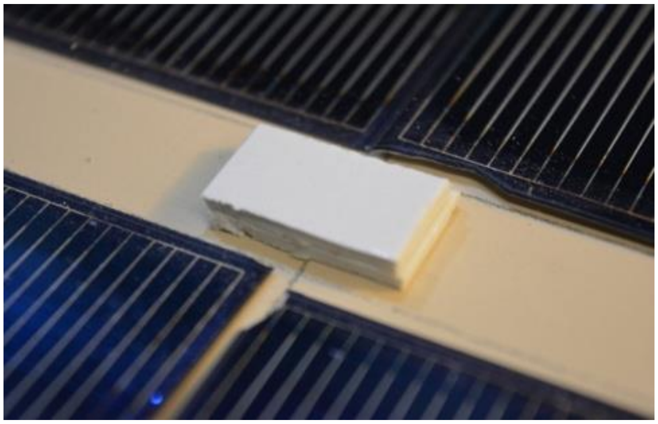
There are a number of clear plastic glazing materials available on the market. Their strength varies, depending on the material. Of course, the stronger the material, the more expensive it is.

Material	Compared to Glass	Relative Price
Glass	---	$17
Tempered Glass	5x stronger	$56
Acrylic	10x stronger	$16
Plexiglass	50x stronger	$22
Lexan	250x stronger	$34

The problem with plastics is that they will scratch much easier than glass will. So, for home installations, most people use glass for their solar panels. However, in this case, where flexibility is an issue, the plastics are better. With proper care, the panels should last for years, without any problem.

So, in order to finish assembling your solar panels, you're going to need:

- Double-sided foam mounting tape
- Clear silicone caulking
- Some sort of glazing material
- Aluminum "C" channel
- Waterproof electrical connector



The first thing we're going to do is to make a sandwich of the solar panel and glazing. In order to do this, start by placing a row of double-sided adhesive foam, the kind that's used for hanging pictures, all the way around the edge of the backing panel, on the side that the solar cells are on. Make sure that your seams are as tight as reasonably possible, without overlapping layers. You want a total of 1/8" thickness of this foam, in order to leave space between the solar cells and the glass, so if your foam is thinner, use a double thickness.

You'll need to run the wires out through this foam as well. The best choice is to pick a place where you already have to connect two pieces of foam, so that you don't have to make any extra seams. Simply leave a gap, the thickness of your wire, and run the wires out through it. Don't make the gap too wide, or you will be providing too much of an opportunity for moisture to enter through the hole.

I mentioned putting a spacer in the middle of the panel as well. This is done with the same foam tape. Simply cut pieces that will fit in that half-inch gap between the cells. If you had to use a double thickness around the edges, then do so here as well. You want it to end up the same thickness. Be careful as you apply this foam tape, as to not put pressure on the edges of any of your solar cells and crack them.

The plastic glazing needs to be cut to the same size as the backing board. There are several ways of doing this, but the easiest is to score it several times with a utility knife and then break it. Cutting it with any sort of saw tends to chip and crack the plastic, although if you are careful, this works well.

The tricky part now is to put the plastic glazing on the panel, without getting it stuck in the wrong place. You only get one chance at this, so you want to make sure that you get it right. My favorite method is to make a 90 degree corner jig out of wood and place the panel in the corner. Then, I can align the plastic with the panel, before lowering it into place.

When doing this, I only remove the paper backer from the corner that I'm going to start from, leaving the "tail" hanging out so that I can pull on it to get the rest of the backing paper free. This corner of the panel is then placed in the wood corner, tight up against the wood. The plastic is placed in position, then lowered into place, paying particular attention to the corner where the adhesive is exposed. Once that corner adheres, the backing tape can be pulled loose to expose more adhesive, working your way around the panel.

Press down on the edges of the panel, all the way around, to ensure a good seal. Excessive pressure is not necessary, just enough to ensure adhesion.

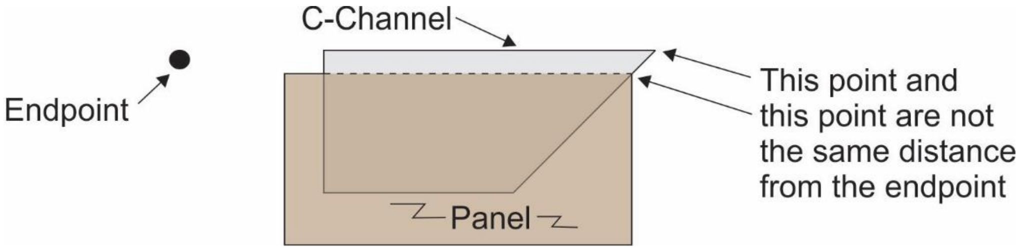
Be careful doing this, that you don't accidentally put any pressure on the solar cells, but rather only on the foam mounting tape. As long as the pressure is localized there, you have little risk of damaging anything.

The solar panel needs to be fully sealed against moisture. Any moisture that gets into it will most likely evaporate and condensate on the bottom side of the glazing, reducing the ability of light to pass through and thereby reducing the solar panel's efficiency.

This is most easily accomplished with standard silicone sealant or caulking. I would recommend using clear, just from an aesthetic point of view. Run a bead of silicone around all the edges, smoothing it into place with a wet finger. You want to end up with the silicone capping the edges of the glazing, the foam mounting tape and the plywood backing board, making them one. However, you don't want excess sealant, as that can cause problems with putting the frame around the panel.

Make sure that you have sealed around the wires that are coming through the foam mounting tape. This is the number one place where moisture is likely to get into your solar panel, so you want to be careful here. At the same time, you don't want silicone three inches up your wire, where it will harm the flexibility of the wire. Allow the sealant to dry fully. This should take about 24 hours. If there is excess sealant, trim it off at this time.

Miter cut the aluminum C channel to make the four sides of the frame. You will want the corners to meet together well, so if you are unsure, cut it long and then trim it down to fit. This C channel can be cut with a power miter saw, a radial arm saw or a table saw with a miter gauge. Always use a carbide tipped blade on these power tools. I would not recommend cutting it by hand, unless you have no other option, simply because it will not be easy to make an accurate 45 degree miter cut.

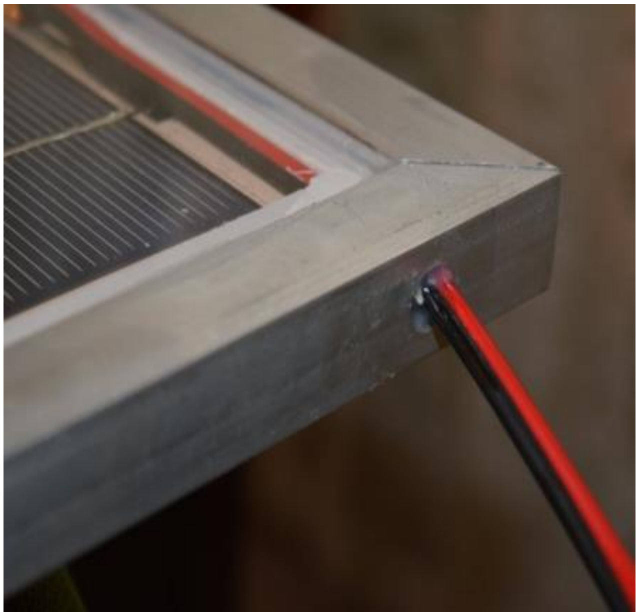


Actually, you'll want to cut the C channel a little long, to make up for the thickness of the material used in the channel. Here's the problem: you'll be measuring it at the outside or back of the aluminum channel, not the inside, where the edge of the solar panel is. So, the distance from the other end of the frame will not be the same distance. In order to make up for this, we use the Pythagorean theorem and find that you have to cut the frame pieces:

- 23/64" (or fudge and make it 3/8") longer if the walls of the channel are 1/8" thick
- 1/8" longer if the walls of the channel are 1/16" thick

Before attaching the frame, dry fit it to the panel, so that you can check the fit of the corners. A small amount of slop (1/16" - 1/8") is acceptable and advantageous. If there is no slop whatsoever, it is hard to get the corners to fit together snugly. Adjust bar clamps to fit, so that they will be ready to install once the frame is attached to the panel.

You will have one side of the frame where it will be necessary to drill a hole through the frame, so that the wires attached to the solar cell string can come through the panel. Measure carefully and drill this hole. Try to avoid making it any bigger than you need to, but you must also allow yourself a little bit of room to adjust the frame onto the panel. Any extra space can be filled with silicone caulking.



Use a countersink or larger drill bit, on both the outside and inside of this hole, to ensure that the hole for the wires doesn't have any sharp edges. Ideally, you want a slight beveled edge, on both sides of the channel. This will prevent the frame from cutting into the wire's insulation and causing it to short out.

Apply two beads of the same silicone caulking to the inside of the C channel. A larger bead should be in the back of the C and a smaller one on the glazing side. Press the channel carefully onto the edges of the panel, forming the frame. Ensure that the corners fit together well.

If there is any space left over in the C channel (there should be) put wedges or spacers inside the channel, against the back of the backing board. I used common door frame shims for this, which are cheap and readily available. This way, the glazing side of the panel will be pushed up against the C channel, ensuring a good seal. Clamp the channel to the panel to dry.

Before the silicone has a chance to dry, wipe off any excess silicone from the front side, especially if it is on the glazing. Allow the silicone to dry overnight.

Remove the clamps from the solar panel and inspect it. If additional silicone is needed around the edge of the glazing or in the corners, apply it now.

Then turn the panel over to inspect the back side. You will probably have a slight gap between the backing board and the C channel (about 1/16"). Fill this gap with silicone caulking to seal it. Allow to dry. Then flip the panel over and caulk the edge of the glazing to the frame.

At this point, the only thing that's holding the frame to the panel is the silicone caulking that we've used. While silicone caulking makes a good adhesive, it is not perfect.

If the frame gets caught on a tree branch, while walking through the woods, it is possible for it to be pulled off. So, we need to add something to strengthen it.

While there are a number of ways of doing this, the easiest is to put corner brackets on the backside of the frame. These will work better than the ones that go on the outside of the corner and won't require us filing the aluminum channel to make it possible for the corner to fit snugly.

In this case, rather than use the #6-32 wood screws that came with the corner brackets, I'm using #8-32 x 1/2" machine screws and tapping holes into the metal frame for the screws to thread into. While I could use the wood screws, there's too much of a chance of the point pushing up against the acrylic glazing and cracking it. Shorter wood screws probably wouldn't hold well, so by using machine screws, I increase the overall strength.

A #8-32 tap requires a #29 drilled hole, which is .1360". I don't have number sized drills, so I used a 9/64" drill bit, which is only .004 (four thousands of an inch) larger. While I will lose a bit of my screw thread with this, the amount I'm losing is not significant. If you choose to use #6-32 screws, you'll need a #36 drill bit, which is .1065". If you don't have that, you could substitute a 7/64" drill bit, which is only .003 (three thousands of an inch) larger.

Drill the hole carefully, so as to not go into the Plexiglas. The foam mounting tape makes a good buffer, as the drill bit will not grab the foam easily and cut through it. Tape the holes through with the #8-32 tap (or #6-32 tap), using a little bit of lightweight cutting oil. You will be able to tell when the tap has fully cut the threads, because it will become easy to turn. Install the screws, to secure the frame.

The only other thing you need to do to this solar panel to make it complete is to attach a connector to the wires. I would recommend using a waterproof connector, such are commonly used in car engine compartments. If the connector already has pigtails on it, you will want to solder it to the wires you've already attached to the solar panel. Do not just twist the wires together. Rather, twist them and then solder them. Using heat-shrink tubing over the soldered joints will ensure well-sealed connections that should not corrode.

Congratulations, you have finished your solar panel! If you are going to make additional panels for your Backpack Electricity generator, do so before continuing on to the next chapter.

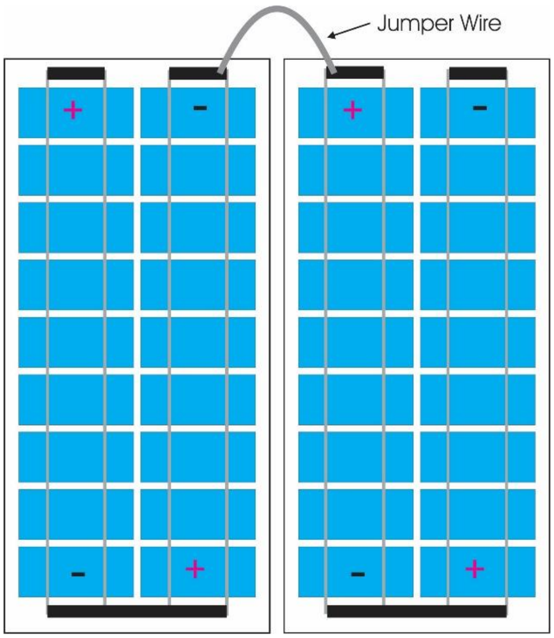
A WORD ABOUT PANEL SIZES

The panel we've just constructed is 26-5/8" x 32-3/16". While that is a reasonable size, and even portable, it might be a bit difficult to carry, strapped onto a backpack. To make up for this, you might want to split the panel into two parts, each containing 18 of the 36 solar cells.

Please note that to do this, each smaller panel won't be producing enough voltage to be useful for much more than charging a cell phone. The panels will have to be connected together in serial, as pairs, before connecting the panels in parallel. To keep from having confusion when time comes to connect the panels together, I'd recommend hinging the panels, so that one hinged pair becomes one panel, electrically speaking. That way, you'll get the required voltage out of it.

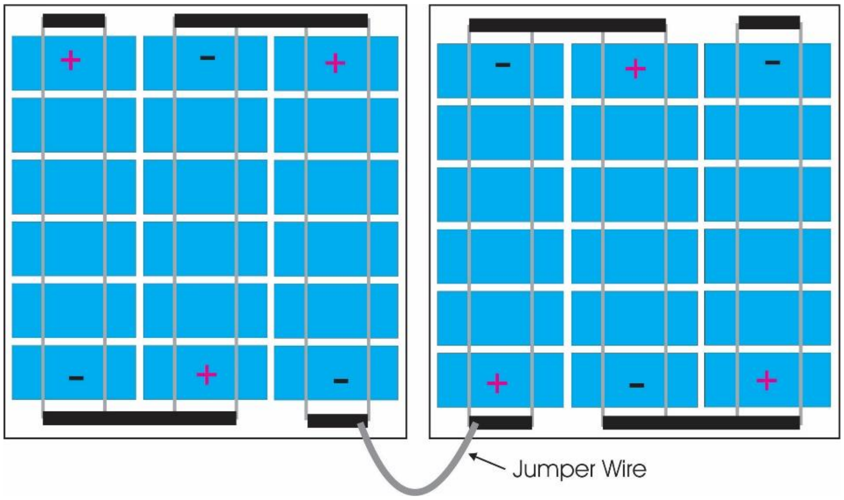
There are a number of different ways in which we can alter the design of our panel, taking the same basic panel we've made and splitting it. Or, we can start from scratch, making a panel which is close to square. Let's look at two possible designs.

In our first design, we're going to split the panel in half, making it so that we have two strings of nine cells in each. This is going to give us a fairly long and narrow panel, measuring roughly 13-5/8" wide by the full 32-3/16" tall. The height of these might cause a slight problem attached to a backpack, if you are traveling through an area with a lot of overhanging branches.



Other than that, these dimensions work out very well for backpacking, as the panel is narrower than the backpack.

Another advantage to this design is that it will be easy to set up. Since the large dimension is the height, the open panel should be able to be leaned against a rock or tree, vertically, pointed towards the south.



The second design we're going to look at is splitting the panel into two panels which each have three rows of six cells. This gives us a panel that is more square, with dimensions of about 20"x 22". While wider than the first split panel design, unless you are traveling through an area where the brush comes very close to the sides of the trail, that shouldn't be an issue.

Either of these panel designs will work equally well. The only real difference is how easily they will attach to your pack, and how easy it will be to move through the terrain you expect to be traveling through. That depends a lot on the terrain and especially the vegetation.

From a construction point of view, making two connected panels is only slightly more difficult than making one and requires only a little bit more material. You will use roughly the same amount of glazing for the panels, plywood for the backboards and exactly the same amount of solar cells and tabbing wire. The difference will be in the one jumper wire you have to install, and the extra aluminum you will need for framing the two separate panels.

You can figure on about 25% more aluminum with this design, as well as the extra corner brackets, hinges and if you decide to use one, some sort of latch to close them together (not required).

DEALING WITH BROKEN SOLAR CELLS

Because solar cells are so fragile, there's a fairly good chance that you might break one while building your first panel. When I built my first, I left it on my workbench and a family member threw something on it, breaking six of the cells. Needless to say, I was anything but overjoyed.

It is possible to remove broken cells that are mounted in a panel, and replace them. The problem comes in when the glazing is installed and the panel is sealed. At that point, taking it apart carries a high risk of destroying the whole thing. But as long as it is still open, there's a pretty good chance that you can remove the broken cells and replace them.

Before doing anything, take a good look at the broken cells and those connected to them. Take special note of the polarity of the wiring. You have to maintain this, or your labors will be in vain. Remember that the back side of the cells is the positive side and the front side is the negative side. So, look to see where the positive leads are coming to that cell from and where the negative leads are going.

You will need to salvage the tabbing wire that is soldered to the negative contacts on the top of your cell, unless you are replacing a cell at the positive end of the string. The reason for that is that the tabbing wire is coming from the positive side of the next adjacent cell, which means from underneath it. You can't get under that cell to solder on new tabbing wire, so you'll need to desolder those tabbing wires from the broken cell. Simply heat the tabbing wire and pull it off with needle-nose pliers, being careful not to break any adjacent cells.

The leads from the back or positive side of the cell go to the top or negative side of the next cell in line. These pieces of tabbing wire can be cut, as new tabbing wire will need to be soldered to the back of the replacement cell.

Once the tabbing wire is desoldered or cut, you are ready to remove the damaged cell. Simply break it the rest of the way, removing the pieces. I've found that a one-inch wide putty knife works well for this. Don't use compressed air to blow out the broken pieces and don't use a vacuum cleaner. Both can break the remaining good cells. Turning over the panel quickly is a good way to get rid of most of the pieces.

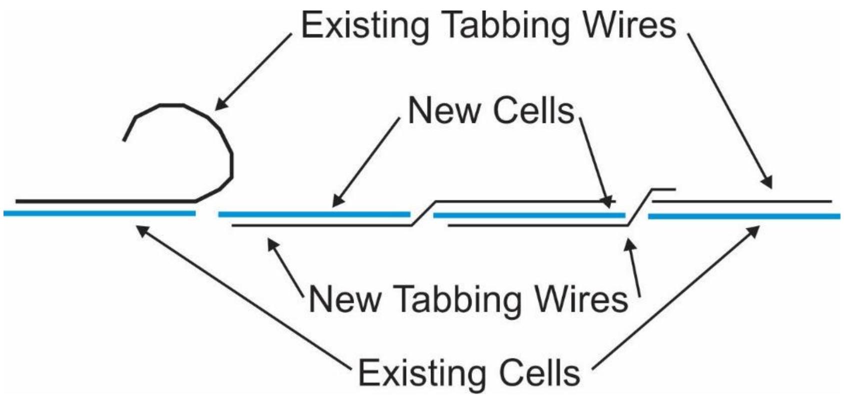
You'll still end up with a small amount of solar cell that is glued to the backboard with silicone caulk. This can be removed with a hammer and chisel, tapping lightly. You'll need a sharp chisel, as it will actually be cutting the silicone. Tap lightly, so as to not overdo it and lose control of the chisel, breaking other cells.

You may very well need to put together a special cell or short string of cells that you can use for your repair. In the photo above, I had to replace two cells together. This required a short string (of two cells), with no tabbing wires connected to the negative face of one cell, but short tabbing wires connected to the positive side of the other cell. The two were connected together by tabbing wire in the normal way.

The short tabbing wires only needed to extend 3/8" past the edge of the cell. That's because I had clipped the tabbing wires from the old cell, leaving tabbing wires attached to the negative side of that cell. The short stubs would be soldered to the existing wires.

Creating the string in this way not only allowed me to attach the positive side of one cell to the existing negative tabbing wires on the adjacent cell, but on the other side use the existing tabbing wires that were coming out from underneath the neighboring cell. Those were soldered to the negative side of the new cell.

Of course, silicone caulking had to be applied to the backing board to hold the new cells in place. Before attaching the cells, I checked three times to make sure I had the polarity correct, as it would be difficult to replace the cells yet again.



This diagram shows which tabbing wires were new and which were existing cells in this repair. Other than the fact that there were two cells together in this one, the necessary work was fairly typical. Take your time to make sure that you have your polarity straight before doing anything and you won't have problems.

Building the Power Controller/ Converter

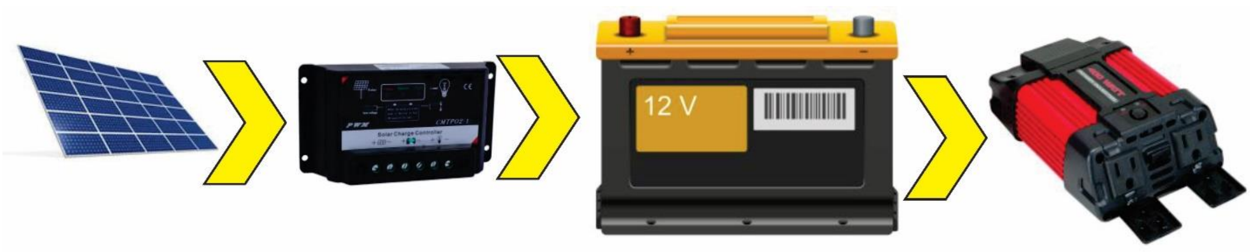
The solar panels produce the electrical power, but that's not enough by itself. For one thing, solar panels are inconsistent. Their output dips when clouds pass overhead, blocking the sun and they don't work at all at night. On top of that, we have to remember that we're producing 18 volts of DC power, not 120 volts of AC power. So, as it stands, our solar panels may not be able to power everything we want... at least, not without doing something to the power they produce.

That's why the power from the solar panel never goes directly to the device it's going to power. I don't care what solar powered system you look at, the electrical energy from the panel is not used directly by the device, not even for something as simple as a solar-powered street light.

Instead, the electrical power from the solar panel is used to charge a battery, which both stores the electricity and acts as a buffer between the panel and the device being powered. This allows the power supplied to be more consistent, making it easier to use.

The one exception to this is some home systems, which are sold without a battery backup. Specifically, these systems are sold by solar power contractors, who are selling them based on the homeowner being able to produce their own power, saving on their electricity bill, not putting in the system for emergencies. They can get away without using a battery bank, because the grid is essentially functioning as the battery for the home, accepting excess power produced and providing power when not enough is produced by the solar system.

While you can connect a solar panel directly to a battery, it is rarely done. Instead, the solar panel is connected to a solar charge controller, which is then attached to the battery. The solar charge controller is a battery charger, but one that is designed to work off of a 12 to 24 volt DC input, rather than one that is designed to work off a 120 volt AC input, like the battery charger that you would use for a car.



With the solar charge controller connected, the solar panels will charge the battery, whenever the solar panel is connected to it and exposed to sunlight. When the battery is fully charged, the charge controller ensures that it does not become overcharged and when there is no sunlight for the solar cells to use for producing electricity, the charge controller prevents the battery from discharging through the solar panel. So, this inexpensive device has a very important part to play in the overall operation of the power generator.

THE BATTERIES

Lead-acid batteries, similar to car batteries, are usually used for storing power produced by solar panels. The main reason for this is cost. While lead-acid batteries aren't exactly cheap, they are an old technology. Therefore, they are the cheapest form of rechargeable battery on the market.

There are two drawbacks to lead-acid batteries, both of which we can work with. The first is that they are rather heavy. Compared to other common rechargeable batteries, they are the heaviest on the market. This isn't a problem in a stationary situation, but for a portable system, like we are building, that can be a problem. For this reason, our basic system is going to use a smaller lead-acid battery.

The other problem with lead-acid batteries is that they don't handle deep-cycling well. Deep-cycling occurs when the battery discharges more than half way. What happens to the battery is that lead from the plates starts flaking off and falls to the bottom of the battery casing. When enough lead falls to the bottom, the cell shorts out and the battery can no longer provide 12 volts.

The solution to this problem is to use special batteries that are designed with deep-cycling in mind. These batteries are sometimes referred to as "marine" batteries or "marine/RV" batteries, because they are often used in boats and recreational vehicles. You can also find them listed simply as "deep-cycle batteries."

The difference in deep-cycle lead-acid batteries is that they are designed with thicker plates and more space at the bottom. That way, even though the plates are still damaged due to deep cycling, the battery remains useable. There is still enough lead in the plates to charge and discharge and the lead which falls to the bottom of the cell doesn't short out the cell. Of course, these batteries will eventually go bad as well, but it will take a lot longer.

When we look at automotive lead-acid batteries, there is one principle figure we are interested in. That's the battery's capacity, stated as "reserve capacity." Please be careful about this, as the more obvious specification is usually the battery's "cold cranking amps." That figure is important if you are using the battery to start a car on a cold morning; but that's not what we are doing. The two specifications are defined as:

- **Cold Cranking Amps** - The amount of power, measured in amps, that the battery is able to supply in order to start a car's engine. This is the maximum number of amps that the battery can deliver for 30 seconds, at zero degrees Fahrenheit. At the end of the 30 seconds, the battery would be at half charge; not enough to start a car.
- **Reserve Capacity** - How long the battery can maintain a constant 25 amp discharge, before the battery is at half charge. A point when the battery is considered to be no longer usable.

Please note that these two specifications are for car batteries. The smaller lead-acid batteries that we are going to use for our basic Backpack

Electricity system aren't rated with these specifications, but rather with the number of amp-hours of power they contain.

That's very similar to the reserve capacity, but it means the amount of amps of power that the battery can provide for one hour.

While we are using lead-acid batteries for the Backpack Electricity unit, it is possible to use other types of rechargeable batteries.

A number of different types of materials have been used for making rechargeable batteries, in the search for a better battery. Better means different things to different people, but it's usually a combination of the total capacity of the battery and the price.

As new technologies are developed, they tend to enter the market at a higher price. As they gain popularity and are more widely used, the cost for these batteries drops. That's why lead-acid and nickel-cadmium batteries are so inexpensive.

Both technologies have been around a long time, so the cost of these batteries is low.

In the last several years, we've seen three different battery technologies used for cordless power tools. They started out with NiCd batteries, moved for a short time to NiMH and are now almost exclusively Li-Ion.

There's also a variant of the Li-Ion battery, called Li-Po for Lithium-Polymer. The change in batteries sued for power tools reflects the advantage of these newer technologies and how readily they are accepted by the marketplace.

The table below shows the comparison between various types of rechargeables, so that you can see the benefits of them.

Property	Lead-acid	NiCd[5]	NiMH[6]	Li-Ion[7]
Energy density	30-50	45-80	60-120	110-180
Cycles in the battery's life - 80% capacity charge	200-300	1500[8]	300-500	500-1000
Fast charge time	8-16 h	1 h	2-4 h	2-4 h[9]
Overcharge tolerance	High	Moderate	Low	Very low
Self-discharge (per month)	5%	20%	30%	10%
Cell voltage	2 v	1.25 v	1.25 v	3.6 v
Cost comparison	$25	$50	$80	$100

As we can see from this table, lead-acid batteries are the cheapest option, as far as outright cost is concerned. But when we compare cost per energy stored, NiCd is the cheapest and Li-Ion is next. However, you should be aware that the price of Li-Ion batteries has been dropping dramatically since this data was collected and they will soon be much cheaper to use; cheaper than any other type of rechargeable battery.

SOLAR CHARGE CONTROLLER

As I already mentioned, the solar charge controller is essentially a battery charger, intended to take the 18 volts from the solar panels and drop it down to an appropriate level for charging the 12 volt battery. It then monitors the level of charge, preventing overcharging. Many solar charge controllers also provide you with a visual indication of the battery's state of charge.

There are many different controllers on the market, each with its own peculiarities. But the main thing you need to concern yourself with is the

[5] NiCd refers to nickel-cadmium
[6] NiMH refers to nickel-metal hydride
[7] Li-Ion refers to lithium-ion
[8] Ni-Cd batteries need to be properly maintained to reach 1500 charge cycles
[9] Although the specifications in the table are correct for charging time, many manufacturers have developed chargers allowing much faster charging times for Li-Ion batteries, as fast as 30 minutes.

unit's capacity. You need to make sure that the solar charge controller that you choose has an amperage rating higher than the total power put out by your solar panels. For this project, I picked a 30 amp controller, although I could actually have gone with a smaller one.

The other factor in the selection of more expensive solar charge controllers is the means by which it charges the batteries. There are two basic differences: Pulse width modulation (PWM) and Maximum power point tracking (MPPT). Put simply, the MPPT is the most common and can gain you as much as 30% more power capacity than the PWM ones. This comes from their higher efficiency.

You may find that lower-cost controllers are not listed as to charge type. That's not surprising, as controllers vary extensively in pricing. The charge type is actually something more associated with the larger solar charge controllers used for home systems.

Some charge controllers also provide a 5V USB outlet. While this is not a requirement and probably isn't a deciding factor in buying a particular charge controller, it is a nice feature to have. With the amount of personal electronics today which charge off of a USB charger, having a USB charger built into the voltage inverter is a nice extra to have.

VOLTAGE INVERTER

Once the electrical power from the solar cells is stored in the battery, it is ready for use. In fact, you can start using the power as soon as the battery is more than halfway charged. Since your typical battery comes from the factory with more of a charge than that, your system is ready to use as soon as you get it put together.

The battery will provide a nominal 12 volts DC, which is fine if you want to run 12 volt devices off of it. But, chances are, that's not what you want to do. So, you'll need to convert that power to what you do need. That's where the voltage inverter comes in. It will take that 12 volts DC and convert it to 120 volts AC.

All voltage inverters are essentially the same, with the exception of their size. The maximum output and sustainable output of the inverter are important figures, which you should look at when selecting your voltage inverter. For the sake of the Backpack Electricity, I've selected a 750 watt voltage inverter, which is actually slightly larger than the basic system can provide. However, it gives me some room for expansion, should I decide to expand the system later on.

When looking at the rating of the voltage inverter, be careful not to mix up the two ratings given. Some manufacturers advertise the "peak wattage" on the box, while others tell you the "continuous wattage." What's the difference between these?

- Continuous wattage is the amount of power the device can output over a long period of time, without sustaining any damage. You can expect it to provide this level 24/7, assuming that there is enough battery power to provide it.
- Peak wattage is the amount of power the device can output for a short period of time, defined as less than 30 minutes, without sustaining any damage. This is usually twice the continuous wattage. If the peak wattage is drawn from the device for more than 30 minutes, it will overheat and may be damaged.

Is it Enough?

Both continuous wattage and peak wattage specifications will be stated in watts. But many of the devices you connect to the voltage inverter are going to have their power requirements listed in amps rather than watts. This can be extremely confusing, but fortunately, it's easy to convert from one to the other, as I told you earlier. Let me repeat it here:

- To convert watts to amps, divide watts by voltage: W ÷ V = A
- To convert amps to watts, multiple the amps by the voltage: A x V = W

So, if you are planning on powering a small refrigerator, which states in the owner's manual that it draws 6.0 amps of power at 120 VAC (that's volts AC), we can easily see if the voltage inverter will power that by multiplying 6.0 x 120, which equals 720 watts. So, my 750 watt voltage inverter will clearly provide enough power for that small refrigerator. In this case, the limiting factor will be the size of my battery.

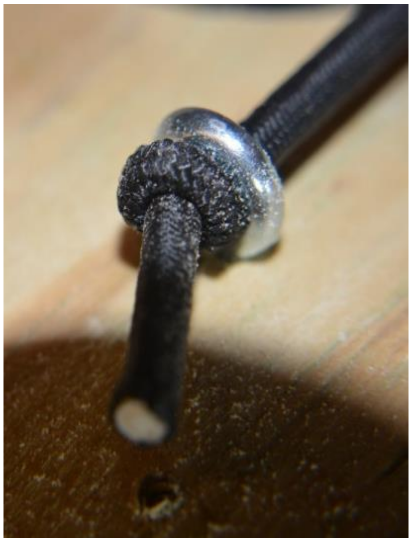
But to multiply the 12 volts 10 times, to equal 120 volts, the voltage inverter needs to draw ten times the amount of watts or amps of 12 volt power. So, that 6.0 amps becomes 60 amps. That's actually quite a bit of power. The small battery I used in the basic Backpack Electricity unit won't be enough for that. I'll need a larger battery, such as the deep cycle marine batteries I mentioned earlier.

A typical deep cycle battery typically has a reserve capacity of 90 minutes. So, when we take into account the actual draw on the battery by the voltage inverter, it would be able to provide the power needed to run that refrigerator for about 45 minutes, before the battery's power dropped too low to be useful. In order to power it for longer, additional batteries would be needed or enough solar panels to provide the 60 amps of 12 volt electricity continuously, so that it could be converted to 6 amps of 120 volt current.

Keep in mind that we are building a portable system, not a whole house system. It is doubtful that you will try to power a refrigerator off of this system. I merely used this as an example, to give you an idea of how you would determine if your system could power your devices.

PUTTING THE POWER CONTROLLER TOGETHER

The pieces of the Backpack Electricity control panel all need to be mounted together and connected electrically. The main reason for mounting them together is to protect them, especially from being disconnected. If the

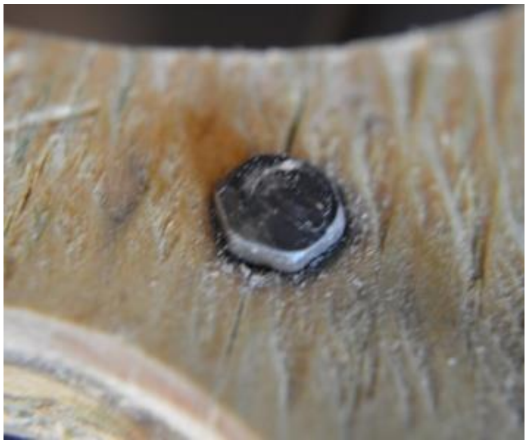


components are merely placed in a backpack and connected together, you can be sure that they will become disconnected.

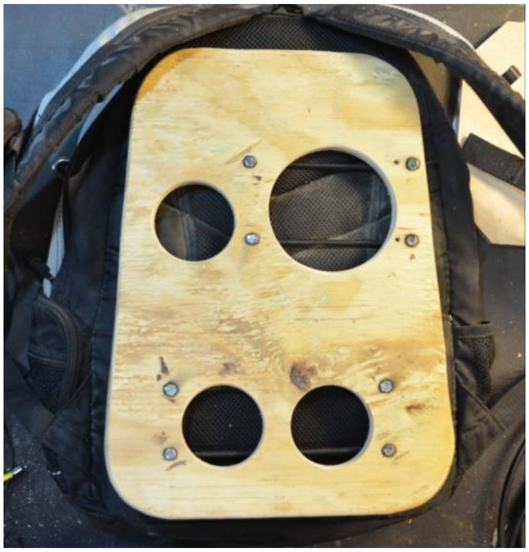
Since this is called "Backpack Electricity" we're going to put everything together in a backpack, making it a portable unit.

While there are other ways of having a portable unit, a backpack has the advantage of being the easiest to carry, leaving your hands free. For the basic unit, we're going to use a day pack.

In order to mount everything together, we're going to need a backing board of some sort. I've selected a piece of 3/8" thick plywood for this.



The thinner plywood is lighter in weight, while still providing a thick enough piece of wood for fasteners. To reduce weight further, I used a hole saw to cut through the backing board behind the various components.



It is extremely important that all sharp edges and corners be eliminated on the backing board, so that there is nothing that will chafe on the inside of the pack and wear through. For this reason, the backing board has rounded corners. The edges, including the inside of the holes made with the hole saw, have also been rounded with a 1/4" roundover bit on a router table.

The solar charge controller I am using has flanges with mounting holes. So all I need to do to mount it is run screws through the holes into the backing board. But I can't do that with the battery or voltage inverter. There are a number of different ways of attaching these components, such as metal angle brackets and plumbing tape. I've decided to use bungee cords, making it easy to remove and replace components as needed.

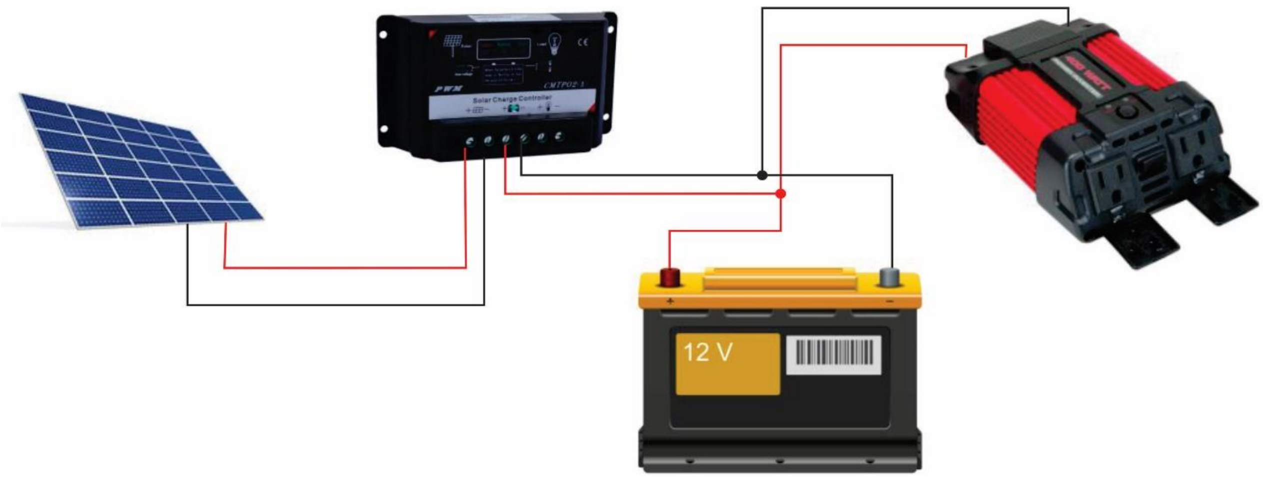
The bungee cord needs something to attach to, which I am providing by using small eye bolts. However, the bolts are too long, causing a risk of damage to the backpack. So, once they are tightened, the excess bolt length has to be cut off with a grinder.

You can either buy bungee cord material (I used 1/4" diameter) or small bungee cords with hooks on the end. For this, I used raw bungee cord and held it in place by running it through the eyes of the eye bolts and knotting it. To prevent the outer casing of the bungee cord from unraveling, I used a lighter to melt the ends of the threads together, much as you can do with nylon rope.

The battery and voltage inverter are fairly heavy, so they are likely to try and slide down the backing board, while the backpack is being carried. To prevent this, I've installed small shelves for them to sit on. The shelves are not the full depth of the battery and voltage inverter, just enough for them to rest on. They are glued and nailed in place with finish nails, as is typically done in cabinetmaking (the main purpose of the nails is to hold them in place while the glue dries).

CONNECTING IT TOGETHER ELECTRICALLY

If you look back at the diagram at the beginning of this chapter, you'll see that the power from the solar panels goes to the solar charge controller, which is in turn connected to the battery. Then the output from the battery is connected to the voltage inverter. While this is technically correct, there's one little problem with that diagram, batteries don't have a pair of input connectors and another pair of output connectors. So, the connection is more like this:



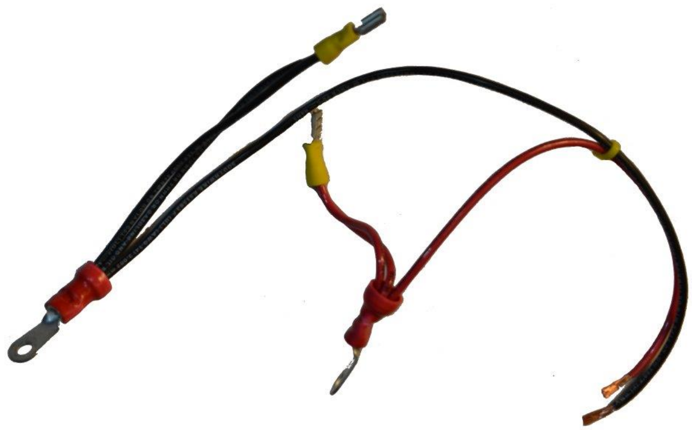
In this second diagram, we see the actual hookup of the wires. The red lines represent the positive wires and the black represent the negative wires. But the most important thing this diagram shows us is that the output of the solar charge controller, the battery and the input of the voltage inverter all connect together. The only real question is where we make that connection.

Electrically, where that connection is becomes immaterial. The electrons aren't paying attention. About the only time the physical location of the connection would be important would be long runs of wire (over 100 feet). So it really boils down to what is most convenient for assembly.

If we were using an automotive battery, I would probably choose to make that connection at the battery. The large connections used for automotive batteries make it easy to connect multiple wires together. We could also choose to use a terminal block and attach all the wires together there. But since we are using a fairly small lead-acid battery, with only 1/4" tabs for connections, I've chosen to connect all the wires at the input side of the voltage inverter, as that has the biggest terminals.

The solar charge controller I selected has screw clamp terminals, which work very well with bare wire.

All you need to do is strip off about 1/4" of insulation and put it in the contact, tightening the screw. But the battery and voltage inverter need better contacts, so crimp-on connectors are used.



Typically, soldering is the best way to connect a wire. But not everything is built to allow soldering wires to it. So, when soldering can't be used, the next best form of connecting is a crimp-on lug or connector. While it is possible for the wire or contact to corrode and eventually cause an open or disconnected circuit, it is not likely, if properly crimped. Be sure to use a crimping tool to ensure good contact and not a pair of pliers.

If you don't have thick enough wire for connecting components together, you can use multiple runs of a smaller wire. For example, two runs of 14 gauge wire have the same power carrying capacity as one run of 11 gauge wire. The determining factor for this is the amperage that will pass through that wire.

Wire Gauge (AWG)	Max Amps
22	0.92
20	1.5
18	2.3
16	3.7
14	5.9
12	9.3
10	15
8	24
6	37
4	60

It is best to connect your wires together, then connect them to the devices. You probably won't have enough room between the various parts to get tools in there and work on them. Building it outside, on your workbench, and then installing them, makes more sense.

Be careful when connecting the wires. The battery should already have a charge. That means that you could get shocked, if you make contact with both the positive and negative terminals at the same time. You could also cause the wires to spark or conceivably weld together, if they touch, damaging the battery.

THE SOLAR PANEL HARNESS

The solar panels will have to be connected to the backpack unit separately, with a separate harness from the one that wires the components of the control panel together. Originally, the design of this unit was for four solar panels. I've built two for the basic unit, but am planning on adding another two as part of expanding it to make the system more capable. So, the harness I built is for connecting four solar panels.

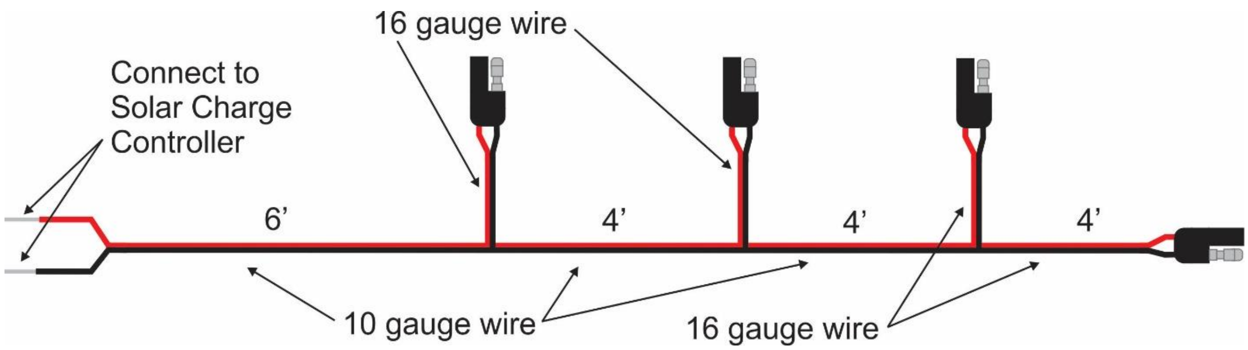
When making your harness, the first thing you need to consider is the gauge of wire you need. It's important to remember that the harness will be carrying the current not only of one solar panel, but of all your panels. Therefore, you're going to need much bigger wire.

A solar panel which is made of 36 - 3"x 6" solar cells produces 3.4 amps of power. So, a single panel can be connected using 16 gauge wire, according to the table above. But four panels are going to give us 13.6 amps. If we try to use that 16 gauge wire, it will overheat, melt the insulation and then quite possibly turn into a fuse and burn out. Hopefully, it won't start a fire along the way.

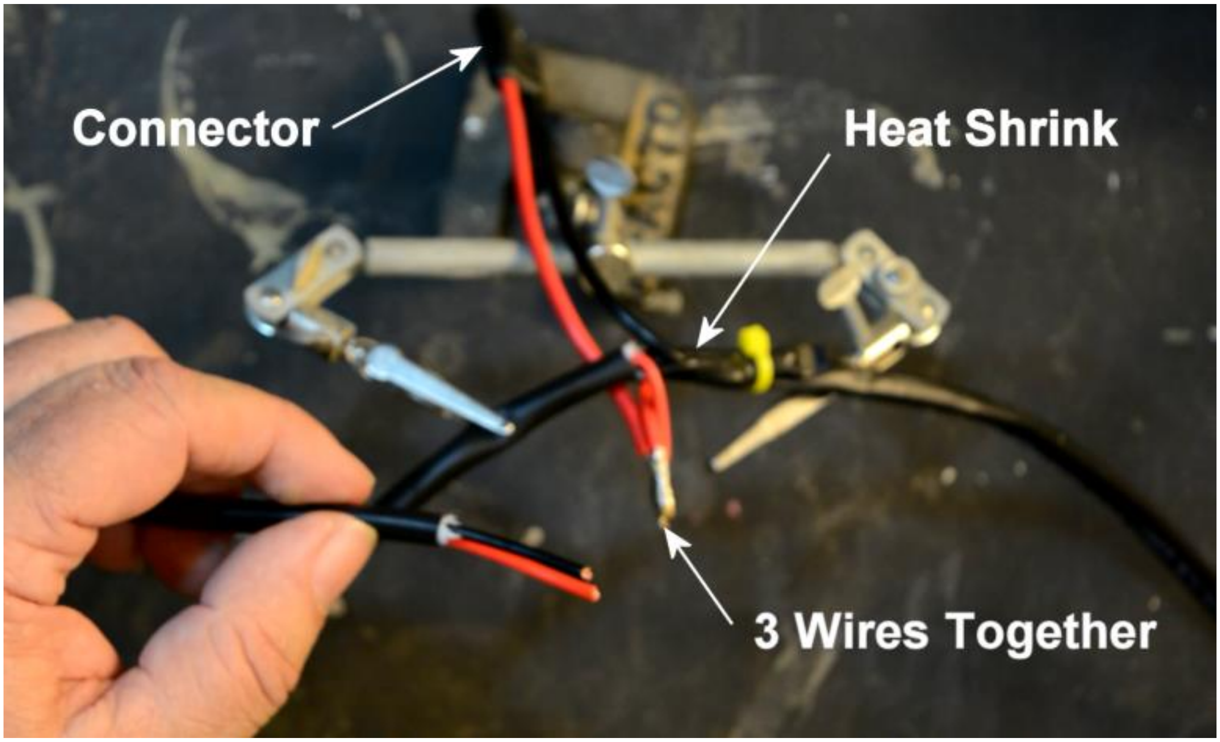
Better to use 10 gauge wire, which has a capacity of up to 15 amps. That way, we're sure of having enough capacity in our wire to be safe.

I used a double-insulated wire, something like a two-conductor extension cord. The individual wires are insulated to protect them electrically; then the wires are insulated once again, together. This is done more for weather protection than any other reason. I did it to protect the wires from physical damage, just as is done with an extension cord. When using the system, the wires might be stepped on or dragged across the sharp edge of a rock. By using double-insulated wire, I help ensure that the inner insulation not be damaged.

You will have to decide for yourself how long a harness you need. I used six feet of wire from the backpack unit to the first solar panel and four feet between panels. That gives me a little extra wire for positioning of the panels and backpack unit. I would recommend that you use that as a minimum, and if anything, add more wire. A few extra feet of wire isn't going to hurt anything.



It is best to solder these connections, so that you will end up with the best electrical connection and so that it doesn't come apart at a critical time. Wires should never only be twisted together, without soldering, as they will eventually fall apart. There are several ways of soldering them, but probably the easiest is to cut the cable, strip 1/2" of insulation off of all three ends, twist them together and then solder them. This also allows the installation of heat shrink tubing, rather than just using electrical tape.



In this photo, you can see the three red wires twisted and soldered together. That's two from the main run of the cable and one from the connector. Once soldered, a piece of heat shrink tubing can be placed over the three wires and heated with a heat gun to shrink it. While it is still hot, if you pinch the end closed with a pair of needle-nose pliers, it will heat seal together, giving you a waterproof covering for your connection.

To prevent the harness from having an elbow at that point, wire tie or tape one of the connected sets of wires to one branch of the main cable and the other to the other branch of the cable. That will cause the connection to be closer to a T or Y, than an elbow with everything sticking out to the same side.

You can also add in another connector at the end that connects to the solar charge controller, if you want. That will allow you to disconnect the harness entirely for storage.

I've simply attached the ends of the wire to the controller and rolled the wiring harness up to store it in the backpack, along with the control panel.

Adding a P-clamp to hold the cable to the backing board helps prevent it from being pulled loose in camp sometime.

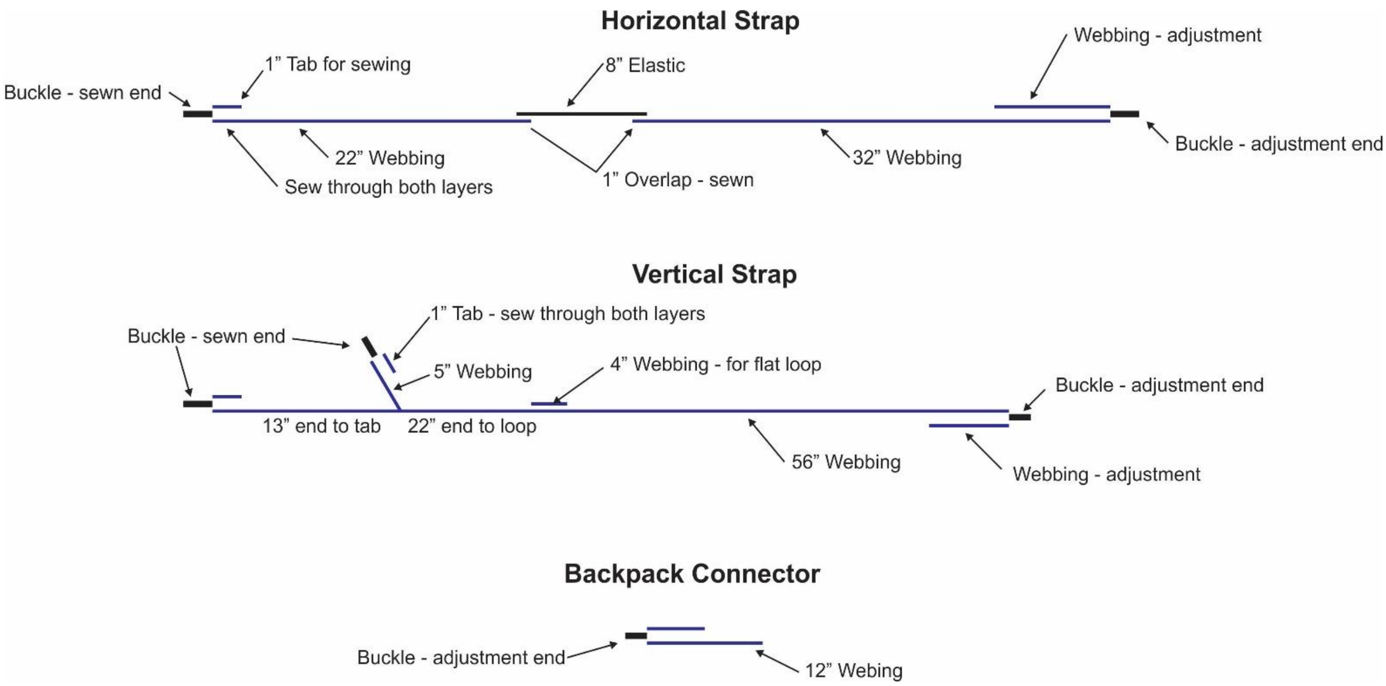
Be sure to use a P-clamp that is small enough that it pinches the cable used in the harness, without being too small.

CARRYING THE SOLAR PANELS

With the way the system is right now, the backpack unit, with the control panel and wiring harness, is easy to carry; but the solar panels themselves are not. They won't fit inside the pack, even if we use the smallest size panels we've discussed. So, we need to add some sort of a carry sling for the panels, which can hang on the outside of the pack.

Once again, this is the type of problem which can have many solutions. The easiest way I found was to make a series of straps, using the 1" wide webbing which is commonly found on backpacks and military gear. The webbing and adjustable plastic buckles are readily available at most fabric and crafts stores.

The strap system I built was for the smaller panels, as I was going for maximum portability. The same sort of system can be used for the larger panels, simply by changing the dimensions. The diagram below provides the dimensions that I used for making these straps.



Notes about the web belts:

- I made 1 horizontal and 2 vertical straps. If you would like greater security, you might want to consider two horizontal straps. If you are using the larger panels, you might even want as many as three straps in each direction.
- All connections between straps, elastic and buckles are double sewn with a 1" overlap. That way, if the first row of stitching starts coming loose, there's a backup row to hold it together.
- The flat loop on the vertical straps is there for the horizontal strap to run through, providing some alignment. I call it a "flat loop" because there is no real reason to make it stand off from the rest of the strap. It can be spread open for the horizontal strap to go through.
- Run the horizontal strap through the flat loops on the vertical straps before attaching it to the adjustment end of the buckle.
- The elastic on the horizontal strap is there to ensure that the strap can be tightened fully, holding the panels secure in the sling. Since the panels themselves are hard, it might be difficult to adjust the buckles in such a way to make the vertical straps tight. With this elastic, at least the horizontal strap will be tight.
- Each vertical strap needs a backpack connector as well, which will have to be sewn to the top of the backpack. The buckle on this tab connects to the buckle sticking out at an angle from the vertical strap on the diagram.
- The strap system is removable, except for the tabs which are sewn to the pack, so that it is easy to access the backpack.

When lacing the buckle, be sure that you work from the side that leaves the outer bar low. Otherwise, the buckle will slip and not stay tight. See the diagram below for lacing the buckle. The same lacing works with all of these plastic tactical buckles, regardless of whether the latch is on the face, as shown, or on the sides.

To use the strap system, the panels will need to have something added to them, to keep them from slipping down. Otherwise, what will happen is that each panel will slip lower than the next, as you move outwards from the backpack. This is easily solved by adding a simple tab to the top edge of each panel. That way, when the panels are stacked together, the tab will rest on the next panel in the stack, holding it in place when the panels are lifted by the straps.

All I did to make this tab is to take a two-hole joining plate, similar to the angles I used on the frame corners, only straight, and cut it in half. It is attached the same way as the corner brackets, drilling and tapping the holes.

Strapped together, the bundle can be hung on the outside of the backpack, using the two buckles attached to the short tabs on the vertical straps.

While it will sway slightly, there really is no problem, as the panels are secure.

You might be concerned about rain, as normally water and electricity don't mix well. The panels themselves are totally waterproof, so that really isn't a concern. Most backpacks are at least water resistant, so the control panel should be protected. However, you can easily cover the entire pack, with the panels, by taking a large garbage bag (33 gallon size) and slitting it on one side. It can then be wrapped around the pack and panels, with the bottom up and the slit along the arm straps of the pack. Hold it in place with bungee cords or duct tape.

Upgrading the Backpack Electricity Unit - Mid Grade

As originally designed, the Backpack Electricity unit was intended to be as inexpensive to build as possible. Not everyone can afford to buy the most expensive equipment out there; and if that is true, then the same people can't afford to build the most expensive equipment either; hence the idea of designing an inexpensive unit to build.

However, least expensive may not always be the best. While the Backpack Electricity unit works as it is, it can be improved upon in a number of ways. We can increase the amount of power it can produce, the amount it can store, how many devices it can run at the same time and even how easy it is to carry.

As with many other similar devices, there are an abundance of different design decisions we can make, each of which will affect the operation and ease of use of the unit. Amongst these, we can find things like:

- A backpack frame to make it easier to carry
- Larger battery capacity to increase the amount of available power
- Changing battery type to lessen weight and increase storage density
- More solar panels to increase power generation

So we're going to look at some ways of making these changes, all the while trying to keep the cost as reasonable as possible. The nice thing about this is that you can decide for yourself what you really need and what you are going to use. In other words, your Backpack Electricity unit can be fully customized to meet your specific needs. Then, if you decide later that you need further modifications, you'll be set to make them also.

This is essentially the same as what most people do for a home power system so that they can get off the grid. They'll start out with a small system, based on what they feel that they can afford. Then, as they can, they add to that basic system. Often, the money for the additions comes from the savings that the basic system gave them on their energy bills.

We're not looking at saving on our energy bills, but the rest is essentially the same. Your Backpack Electricity unit can and should be expanded on, as you can afford the time and money to do so. That way, you'll end up with a much more powerful and capable unit, which can provide you with better service and allow you to operate more electronics in the case of an emergency that shuts off your electrical power.

Of course, the Backpack Electricity unit can be used at home, just as it can be used away from home. The main reason that we made it as a backpack unit is for portability. But that doesn't impede its ability to act as the center of your home power production as well.

So, let's get started on some improvements.

BACKPACK FRAME

The original Backpack Electricity unit was designed and built using a day pack that I had sitting around. The main reason for this was to save money. Most people I know have a day pack or a kids school backpack sitting around somewhere. So I didn't feel that I was misleading anyone by not including that cost. Besides, backpack prices are all over the map.

In reality, I would expect anyone using the Backpack Electricity to combine the unit with their other pack needs. While I'm building it so that one person carries the unit, I can easily see a family splitting it up, with one person carrying the control panel and battery, while other family members carry the solar panels.

One thing that I think would be extremely practical as an improvement to the basic Backpack Electricity unit is the ability to carry it and a pack as well. In order to do this, it will be necessary to use a backpack frame, and not just a day pack.

Backpack frames allow you to carry much more weight than you can in a simple rucksack or day pack. They do this by transferring the weight of the pack to your hips, rather than carrying the weight on your shoulders. The strongest muscles in your body are in your legs and butt, while some of the weakest muscles are in the back. So, it's much easier to carry that extra weight if we can bypass the back and get it to the legs directly. The belt and its accompanying belt do that quite well.

A backpack frame really doesn't work without a belt. The frame transfers the weight to a padded belt, which is snug around your hips or just above your hips. You want it there, rather than around your waist, so that the weight is transferred to your hips and not your lower back.

The shoulder straps on a backpack frame are there more to help balance the pack and hold it in place, than to carry the weight. Properly adjusted, there should be almost no weight on the shoulders, just the pressure of the straps holding the pack in place.

With this addition, we can replace the small battery we used on the basic unit with a larger battery, like one of the deep cycle batteries I was talking about earlier, or even a regular automotive battery, if you happen to have one sitting around. That's going to weigh somewhere between 30 and 50 pounds, but with the frame, it's not really any harder to carry than carrying the basic unit.

So, I'm going to build two different backpack frames for use with the Backpack Electricity unit. I could buy one, but they are actually quite hard to find. It seems that most backpacking packs now use an internal frame, so you can't buy separate frames. The only one I could find was for an Army Alice pack. Besides, building the frame follows our goal of saving money. It's bound to be cheaper to build than to buy.

The two materials I'm going to use are wood and steel. I'd rather use aluminum than steel, but I don't have the ability to weld aluminum. So instead I'm going to have to stick to thin-wall tubing. Since I can use 22 gauge tubing, it's really not going to be all that much heavier than aluminum would be, as the aluminum would have to be thicker.

Wood Backpack Frame

For the wood backpack frame, I've chosen to use Poplar. My main reason for that is that poplar is the least expensive hardwood you can find at your local building materials or home improvement center. Both Lowe's and Home Depot carry a variety of sizes of poplar boards, including thin ones. I'm avoiding using pine or "whitewood" simply because of the reduced strength and difficulty in working with the wood, especially with small pieces.

Poplar is a good choice for other reasons as well. It's a lightweight hardwood, with a fine grain. While not as dense as some other hardwoods, such as oak and maple, it is strong enough for our needs. The fine grain makes it easy to cut curves, without the blade trying to follow the grain.

The wood pieces I bought for the backpack frame were:

- 2 ea. - 1" square x 3' long square dowels
- 2 ea. - 1/2" x 3-1/2" x 2" boards
- 1 ea. - 1" x 3" x 6' board

The basic structure of the pack frame is an "H" with two crossbars. I've added two pieces at the bottom, perpendicular to the frame and horizontal to the ground when the pack is worn, to add support for the battery and allow for connecting the frame to the belt. The picture on the right shows what the frame looks like when done.

To start with, we need to cut the crossbars. These need to be curved, so that they don't sit directly against the back. Were we to leave them straight, they would create pressure points right on the spine. The pattern for these two pieces is in the appendix. They are identical and are cut from the 1"x 3"x 6" board.

I cut these pieces on a scroll saw, but they can also be cut on a band saw or with a jig saw, depending on what you have available to you. If you have any trouble following the curve of the line, cut outside it and then use a belt sander to remove the last little bit of material. It's a good idea to sand the outer curve on a belt sander anyway, to smooth it out. The inner curve will need to be sanded with a drum sander. I put the sanding drum in my drill press, but you can use it in a hand drill as well.

The straight ends of the crosspieces are for use as tenons, to attach the crosspieces to the vertical pieces of the frame. This is important for the frame's strength. If we were to use glue, nails or screws, the frame would be wobbly and the joints would not be strong. Glued joints into end grain are not reliable, nor are screws into end grain. Nails will hold, especially coated nails, but it will not be a wobble-free connection.

We want the tenons to be 1/2" square. If they are any larger, we'll have to cut such a large hole in the vertical pieces, that we will weaken them too much. At 1/2", we'll end up with 1/4" of material on both sides of the tenon, which will be enough to provide the strength we need.

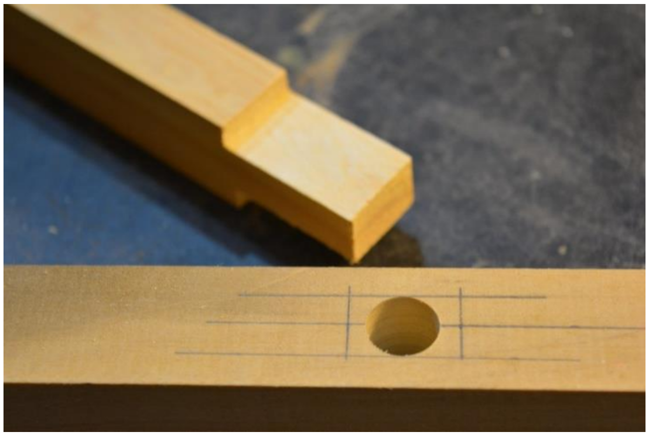
You will have cut the 1/2" dimension in one direction for the tenons when you cut out the crossbars. To make the other dimension 1/2″ (the dimension for the thickness of the wood), we'll need to use a router table or a dado blade on a table saw. Set a straight or rabbeting bit for a 1/8″ deep cut on the router table and run a test cut on some scrap to check that you are not cutting off too much material.

In order to make the cuts straight, use the off-cut scrap pieces from when you cut out the crossbars as a jig. Simply nest the crosspiece in the scrap and hold the two together against the router table's miter gauge.

If needed, clean up the tenon with a file to make sure it is square and that its width stays consistent.

Note: If you don't have a router table, you can skip the above step about routing the sides of the tenons. This means your tenons will be 1/2″x 3/4″. That will make it a little harder for you to cut out the mortises in the vertical pieces, but it will be much better than trying to cut the material thickness down by hand or by using a handheld router. You will merely need to make the mortises larger, 1/2″x 3/4″, with the 3/4″ dimension running lengthwise in the frame member.

Before cutting the mortises, cut the two pieces of 1″ square poplar off to 26″ long.



Mark the center and outside edges of the mortises on the vertical pieces of the frame for drilling. They should be two inches from the bottom end and three inches from the top. (Marking in picture is for a 1/2″x 3/4″ tenon.) Using a 1/2″ drill bit[10] and a drill press, drill

[10] A brad-point drill bit is best, as it allows you to very accurately locate the center of the hole. If you don't have a brad point drill bit, mark your hole center with a center punch, then start with a small bit, working your way larger in stages. Spotting the center of a large drill bit is extremely difficult.

through the vertical members at the four mortise locations.

Note: If you don't have a drill press, I'd recommend drilling half of the way through the vertical members from each side. That way, if your hole goes in at an angle, you will still end up with a hole that is straight through the member.

Using a hammer and sharp wood chisel, clean out the corners of the mortises, making them square. One secret for cutting mortises is to cut them half-way from each side, rather than to try to do everything from one side.

Another secret is to try to cut them as if you were trying to make them concave, rather than flat sided, scooping into the remaining material towards the middle of the board. That will help you to counter the natural tendency for the mortise hole to be smaller in the middle of the board, than it is at the outside. If needed, clean up the corners with a square file.

Mortises are always individually fitted. In other words, your four mortises may not be the exact same size, just as your four tenons may not be the exact same size. Mark each pair as you fit them, so that you can be sure to match them back up when it's time to glue the pieces together.

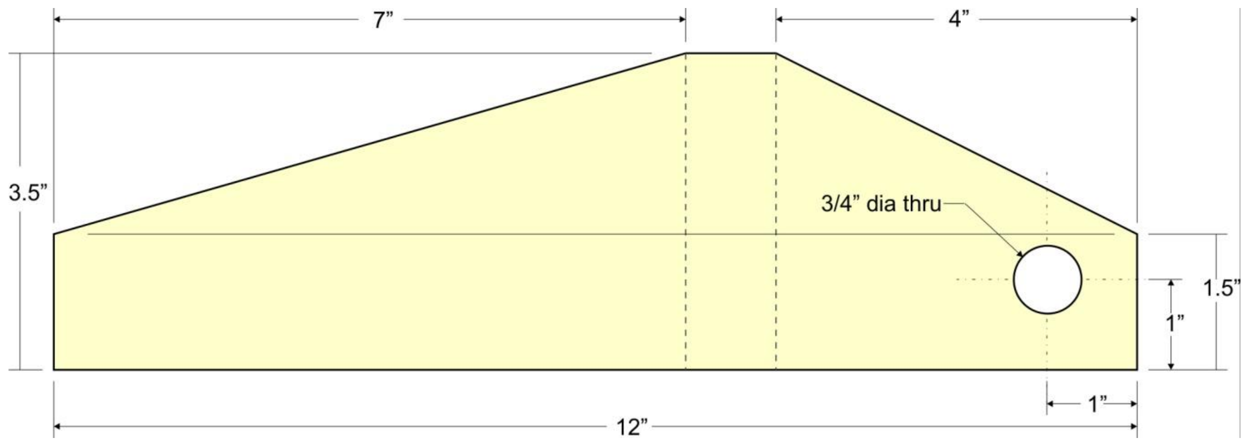
Ideally, your mortise and tenon joints will be snug enough that you need to use a rubber mallet to put them together. But you don't want to make them so tight that you have to use a sledge hammer to get them together. You still need space for the glue.

Once everything is fitted, take it all apart and reassemble it, gluing the tenons into the mortises. Clamp it all together with a pair of bar clamps and leave it for the glue to dry.

If you used the pattern supplied, you'll notice that the tenons stick all the way through the side pieces, leaving about 1/4" of extra tenon exposed on the outside of the frame. In my experience, whenever I try to cut a tenon exactly the right length, I end up with it a little short. So, I cut mine a bit long and then use a flush cut saw to cut off the excess after assembly. A little sanding and it ends up perfectly smooth.

While this makes a basic backpack frame, we want a bit more. We need to be able to attach it to a belt and we need a shelf to support the weight of the battery. While it's possible to tie the protruding lower ends of the backpack frame to the belt, adding a piece will hold the backpack frame away from your body and help its balance.

These two pieces will be cut out of one of the pieces of 1/2" thick poplar mentioned above. The full pattern for them, with dimensions, is in the appendix, but here's a smaller version:



The two dashed lines on the drawing are there to reference how these braces align with the vertical members of the frame. Draw them in, with a pencil and square, so that you can use them for reference.

These two brackets are attached to the bottom of the frame, on the outside, one per side. The shorter side of the bracket goes forward and the larger side goes to the back. This is a little tricky to do, as there is no easy way to clamp everything in place for attachment. What I ended up doing is to temporarily clamp it in place, using the lines to properly align it, and put one nail in it, at the end farthest from the clamp, as shown in the photo on the left below.

Once I had that nail in place to hold one side of the bracket in place, I removed the clamp and used a carpenter's rafter square to ensure that the bracket was perpendicular to the frame, as shown in the picture on the right. Holding it against the square with one hand, I nailed it with the other.

The brackets were now attached to the frame, but I was not satisfied with their stability. So, I drilled two holes through the brackets and into the frame, so that I could dowel it. I decided on this, rather than using screws, mostly because in a case like this, where you are drilling through one piece and into another, it is actually easier to use dowels, than having to drill and countersink a hole and then install the screw.

Dowel pins used for connecting wood in this manner are ribbed, making their outside diameter slightly larger than the dowel's nominal dimension. That allows for a snug fit. Drill the hole the nominal dimension and then apply glue to the outside of the dowel pin. Hammer it home and allow to dry. If there is any excess dowel sticking out, it can be cut off with a flush cutting saw. If you look, you can see the cut off dowels in the photos above.

The final step in making the wood backpack frame, is to attach the battery shelf to the bottom of the bracket. This was cut from the other piece of 1/2" thick poplar, and spans the two brackets on the longer side. I chose to use coarse thread 1-1/4" long drywall screws for this, as screws threaded into the cross-grain of wood form a very strong connection. In this case, the screws made a stronger connection than the dowels would have.

Because the brackets are only 1/2" thick and how close the screws would be to the end of the wood shelf, I was concerned about the screws splitting the wood. So, I drilled and countersunk clearance holes into the ends of the shelf and pilot holes into the bottom of the brackets.

By measuring and marking these holes, rather than aligning the pieces, I was able to force the fit to be square, just in case something was a touch off.

Steel Backpack Frame

The steel backpack frame is similar in design to the wood one, with the exception of the materials used and that it is welded, of course. The materials list consists of:

- 8' - 1" square steel tubing, 22 gauge
- 2' - 1/8" x 1-1/2" steel strap

I use the cheapest of the cheap wire feed welders for my metalworking projects. I've had it for years and don't know if the same model still exists, but I have found comparable ones available, ranging from $100 to $160. It can technically only weld material up to 1/8" thick, but that's thick enough for my purposes. Although I have to admit, I've built a few trailer hitches and trailer frames with it that required welding 1/4" thick steel.

The main reason why I use a wire feed welder is that, as I've said for years, you can teach a monkey to weld with one of them. So, I figure there's hope for me. I don't weld often enough to get good at it, but like having the capability when I need it. Welding with a wire feed is much easier to handle, as your hand is closer to the work than with a "stick" arc welder and it doesn't require the finesse of a gas welder.

If you've never welded, I'd recommend practicing a bit, before trying to weld a real project. It takes a bit to get used to the circular motion that is needed for a good weld joint. You also need to get used to gauging how the metal is melting. You have to match the speed of your weld to the "puddle" of melted metal, so that it will connect properly.

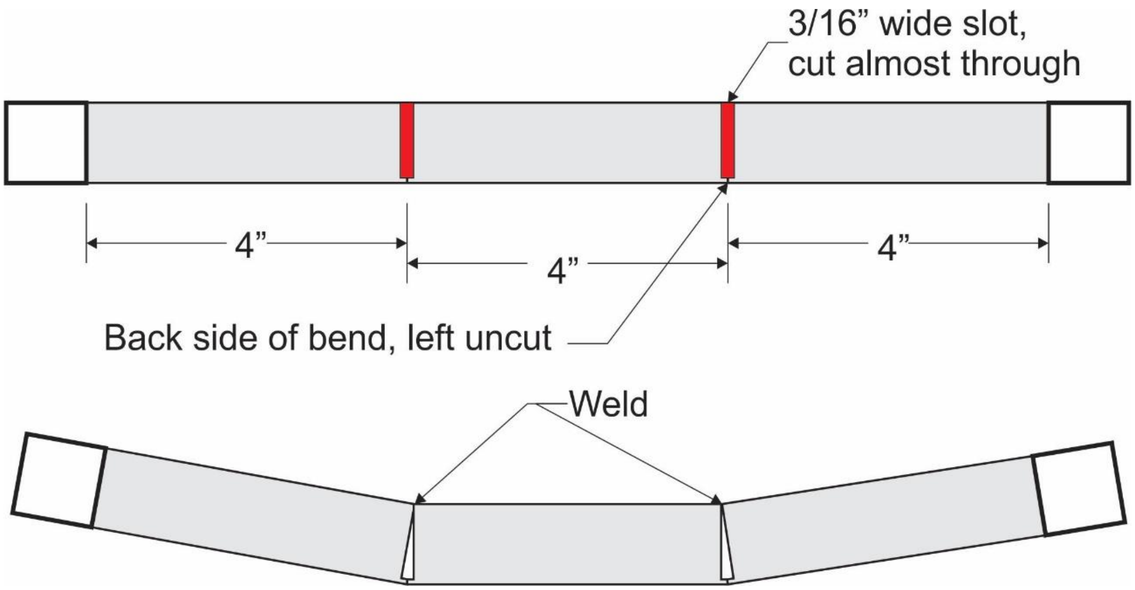
To help with this, I'd recommend always welding in bright light. I normally do all my welding outdoors in direct sunlight (although in the video, I did it in my workshop. If you can't see it, you can't weld it). Welding produces a very bright light, which requires some pretty heavy eye protection. But all you end up seeing is the weld itself, without the bright light, you can't see the metal you're trying to weld. That can cause some rather humorous errors, like welding off at an angle to the seam you think you're welding.

You also need something to use to clamp the pieces you are going to weld together. The most common means of doing this is with Vice Grip clamps. However, there are also magnet corner clamps which work quite well. My personal favorite, which is not a normal welding method, is to use corner clamps, like you would use to make a picture frame. I find that they are easy to work with, don't get easily damaged by the welding sparks and hold the 1" square tubing we are going to use very securely, guaranteeing a 90 degree angle.

Welding requires adequate safety equipment. This consists of a mask with a dark tinted glass viewing port and heavy insulated leather gloves. Don't try getting by with just goggles, unless you like having a sunburned face. The light and heat from welding will give you the equivalent of a nice sunburn, if you don't use a full mask. The gloves are to protect your hands, so you don't burn them. Welding gloves are long, going halfway up your forearms. If you ever weld overhead, you'll also need a leather welding jacket to keep from getting burnt by the hot sparks flying off the weld.

To start with, cut 2 pieces of the 1" square tubing, 26" long and 2 pieces that are 12" long. These will form the H with the double crossbar that we had in the wood backpack frame. Like that frame, we'll want to curve the crossbars. But that's a little harder with metal, than it is with wood. If we had a tubing bender, we could do it, but I don't have one of those available and I'm assuming you don't either.

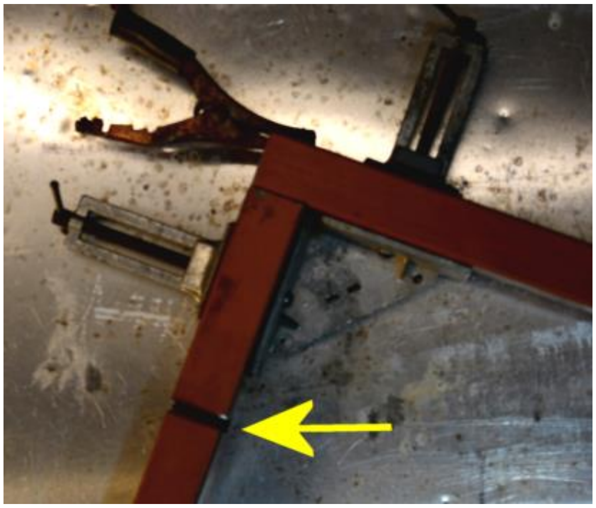
So instead, we're going to make a squared-off curve. This is actually quite easy to do. All we need to do is cut the tubing most of the way through and then bend the opening closed and weld it. By almost all the way though, I mean that you need to cut three sides, while leaving one side uncut. That side will become the outside of the squared-off curve.



The easiest way to handle this is to cut the pieces and weld the double crossbar H together, before bending it. That way, we have a flat structure to put together, rather than trying to work with things at an angle. This is going to cause the vertical bars of the frame to be at an angle to the plane of the backpack, as you can see in the lower part of the diagram above (the vertical bars are the thicker squares on the ends), but that won't hurt anything.

As you can see in the photo below, the corner clamp works quite well for holding the corner pieces aligned for welding. Personally, I find this better than using the magnetic corner pieces, which I also have. The one thing I can be sure of is that the corner will come out at 90 degrees.

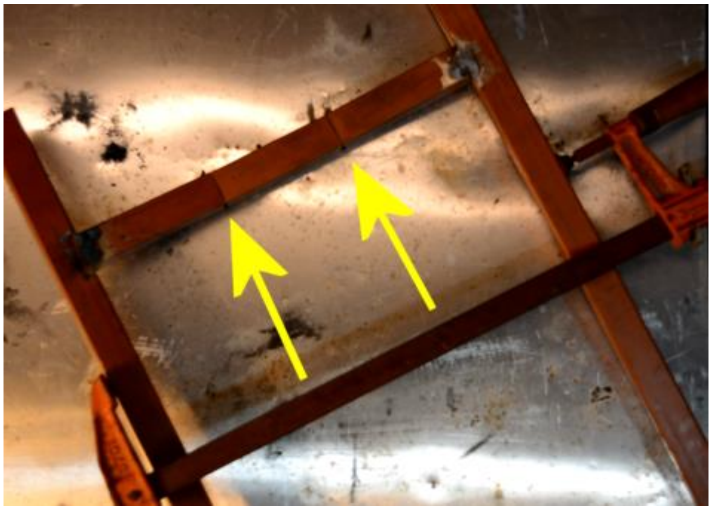
The large alligator clamp in the photo is the negative lead from the welder, which must be attached to the metal somewhere to complete the electrical circuit. I am using a piece of aluminum sheet on my workbench for this weld, to protect the workbench top from burning, rather than welding outdoors, so that I can photograph and videotape what I am doing.



The dimensions of this backpack frame are slightly different than the other. In this case, the lower backpack crossbar is flush with the bottom of the vertical members, as shown in the photo. The upper crossbar is four inches below the ends of the vertical members.

Once you have welded all the joints, it is necessary to clean off the welds and grind them. This allows you to remove the weld slag, as well as check the quality of the weld. If the heat did not penetrate the metal you are welding at some point, the welding wire will merely sit on top of the metal and will not melt into it. This will become obvious as you grind off the excess weld. Fortunately, if that happens, all you have to do is re-weld the joint in question. We're not after style points here, we're after a weld that will hold the frame together.

Don't overdo it on the grinding though. The metal you are using is very thin. You could very easily go through it, or at least through your weld to the point where you cut the seam.



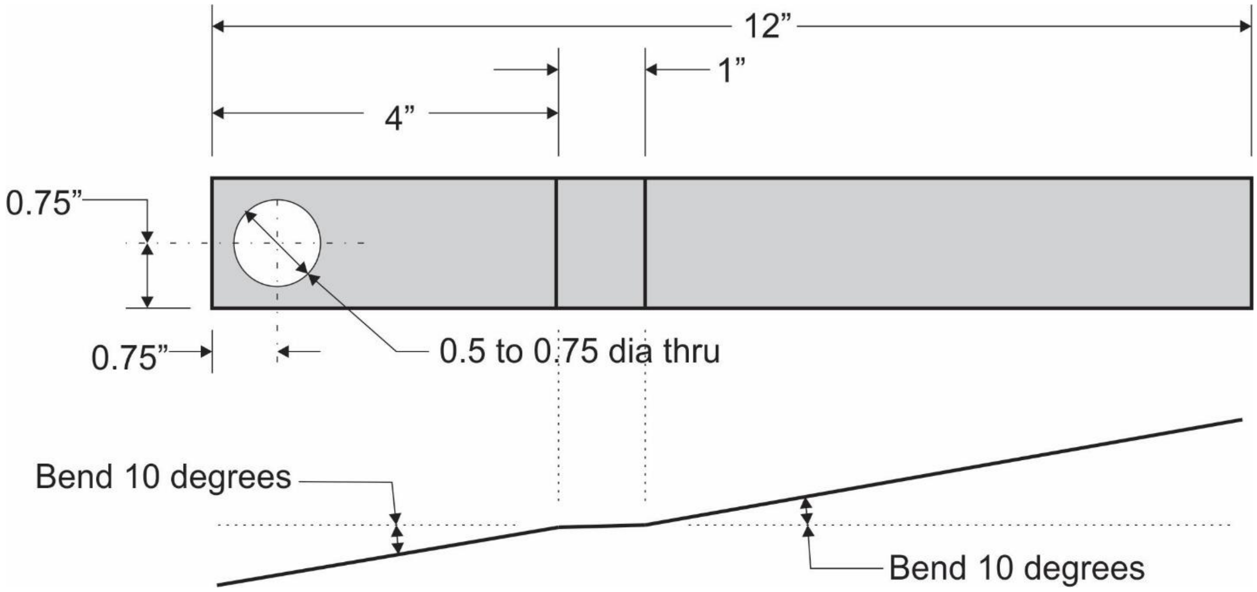
Once the four corners are welded together and the welds ground smooth, it's time to bend the crossbars and weld them to put the curve into them. As you can see in the photo on the right, I have the slot cut for bending the crossbar, but it is not yet bent. Now with the four pieces connected together, I can bend the two crossbars at the same time and hold it bent with bar clamps while I weld the cross-members at the bends.

These bends only need to be welded where they come together, top and bottom. While you can weld them all the way across the seam, it's not really necessary.

About the only reason for that would be to seal off the seam, so water can't get in. I use a bit of automotive body putty for that, as it's easier. I also use body putty to plug the ends of the vertical tubes and make it waterproof.

The next part we need to work on is the shelf bracket, which is also the point of contact for the belt, just as on the wood frame. This is cut from a piece of 1-1/2" x 1/8" thick steel strap, according to the drawing below.

You can also find this drawing in the appendix.



The hole for the shoulder straps and belt to connect to is marked on this drawing as being anywhere from 0.5" to 0.75." That's based upon what size drills you have available to you. I would recommend drilling this hole in 1/8" stages, on a drill press. That will reduce the total heat produced, making your drill bits last longer. It will also help prevent the hole from becoming lopsided. You should also use some cutting oil when drilling through steel. If you don't have any cutting oil, motor oil will work just fine.

As you can see in the drawing, the shelf brackets need to be bent to fit the angle of the vertical members of the frame. When we put the curve into the back piece, it made the sides angled, instead of square to the plane of the pack frame. So, to make up for this, we need to put two - ten degree bends into the brackets.

Cut the two shelf brackets and drill the holes for the belt and shoulder straps first. Then, mark them with either a soapstone marker or a permanent magic marker, for the two bends. To bend them, simply put the piece in a vice, with the bend line exactly at the top of the jaws and tighten down the vice. Check to make sure that the piece is perpendicular to the jaws with a square. Then, hit it a couple of whacks with a fairly heavy hammer (a 3 pound hand sledge works nicely). Check your bend with a protractor.

While the angle of these bends don't actually have to be perfect, the closer to perfect you can get them, the better your frame will look. If they are not perpendicular to the plane of the frame, once welded, it will look a bit strange.

Deburr the pieces with a file and then clamp them to the bottom of the frame for welding. Once installed, they should be flush with the bottom of the frame and perpendicular to the vertical bars. Actually, they should be perpendicular in both directions, with the "ears" of the brackets parallel to each other.

I found it easiest to clamp the pieces in place with welding vice-grips and then check them with a square. Even though they are clamped, they can still be adjusted with a couple of taps from a hammer. Weld the brackets, top and bottom, to the vertical members of the frame.

Please note that it is important that the shorter leg of the shelf bracket, the one with the hole in it, should be facing forward. That's the concave side of the backpack frame. Double check this, before welding.

This is a tricky weld to make, as the thickness of the shelf brackets is about four times the thickness of the tube walls. The secret to this is to modify your ciurcular welding pattern, so that you are spending 80% of your time on the thicker piece (the bracket) and 20% of your time on the thinner piece (the vertical member). That way, you won't burn through the thinner metal of the square tubing.

If you do burn through, you can fill the hole by welding around the edges of it, until the hole is closed. That will leave a lot of weld to grind, but it will end up looking good and be very strong.

The last pieces to be welded in to place will be two crossbars for the shelf. You can cut these from the same square tubing that you made the frame from. They should be 14" long, but measure the space between your shelf brackets to be sure. If your angle isn't exactly perfect, your shelf brackets may not be exactly perpendicular to the plane of the frame and you may need to adjust the size of your crossbars. Or, you may choose to still use 14" crossbars and bend the brackets to meet them.

Clamp the crossbars in place with bar clamps and weld them to the brackets. One should be at the outer limit of the longer leg of the bracket and the other should be about one inch from the convex side of the lower frame crossbar.

Clean up all your welds and grind off any excess lumps of weld. If there are any seams that are not well connected, reweld them before finishing your pack frame. Then, once everything is done, the backpack frame can be painted with an oil-based paint for metals.

Belt and Straps for the Backpack Frames

As I said earlier, the purpose of a backpack frame is to allow you to carry more weight comfortably, by transferring the weight directly to your hips, not your shoulders. This keeps your back from having to hold up the weight, making it much easier to carry the pack. But to do this, we are going to need a backpack belt and straps. The same belt and shoulder straps can be used for both types of pack frames, depending only upon what you decided to build.

It is possible to salvage the backpack belt and straps from another frame, or from a frameless pack, assuming that you have one to salvage them from. However, most of us don't have that sitting around the house. So, we're going to make our own, using readily available materials.

There are a number of ways of doing this, but I've chosen a fairly simple one. In order to avoid having to make a belt, I'm using an Army "Alice" belt. This is the belt that was used in conjunction with the Alice pack or with the older style of "Load Bearing Equipment" (LBE), essentially a belt and suspenders to hang canteens, first-aid kits and magazine pouches on. It has since been replaced; but you can find Alice style belts at any Army Surplus store for less than $10.

We're also going to need a few other things:

- 64" of 2" wide webbing
- 50" of 1" wide webbing
- 2 - plastic buckles for 1" wide webbing (the ones with the side releases are better)
- 12" of 1" wide, heavy-duty elastic
- 12" square of 1/2" to 1" thick foam rubber sheeting (can be salvaged)
- 5 washcloths (dollar store variety)
- Duct tape
- Needle and heavy-duty thread (button thread)
- 2' of Paracord (also known as 550 cord)

We are going to make four separate pieces, two of which are the arm straps and will be the same. The other two pieces are the belt and a comfort strap, to help keep the frame from sitting heavily against your back. You may decide to make two comfort straps. If you do, you'll need another 2' of 2" webbing and 12" of elastic for the second comfort strap.

You're better off using polypropylene webbing than cotton webbing. If you use cotton, you need to sew the ends, to keep them from unraveling, essentially hemming the ends. That doesn't work out too well with threading them through buckles. Polypropylene or nylon webbing can be heated with a butane lighter, melting the ends to seal them together. In this way, you don't need to hem them.

I hand sewed my straps together, but you could use a machine, if you have one available. Since what we are sewing is only one inch long, I decided that the machine would be more trouble than it was worth.

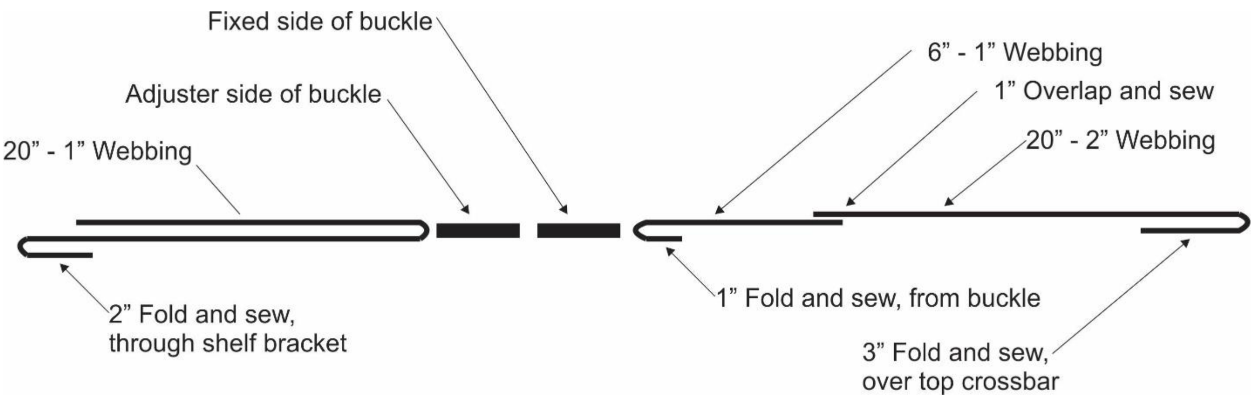
We will be attaching 1″ and 2″ webbing together for the arm straps and 1″ elastic to 2″ webbing for the comfort band. This is not as difficult as it may seem. The two are sewn together, with a 1″ overlap, as shown on the left photo below. Notice that there are two rows of stitching for extra security. Then, the corners of the 2″ strap are folded over and sewn, giving a smooth transition from one with to the other. Just make sure that you mount it to the pack frame in such a way as to have the connection on the back side of the shoulder strap, and everyone will wonder how you did it.

The comfort strap is sewn the same way, except that the 1″ wide webbing is replaced by 2 pieces of 1″ wide elastic, stacked together. This makes the elastic stronger. It is not absolutely necessary to fold over the corners and sew them, if you so decide, as the strap won't be visible when the unit is used.

To make it, start with a 24″ piece of 2″ webbing and 2 - 6″ pieces of elastic. The elastic should not need the end heat sealed to keep it from unraveling. Sew the elastic to one end of the webbing, stacking the two pieces together. Then, sew it to the other end of the webbing, in the same way, ensuring that you don't end up with a twist in the webbing or the elastic.

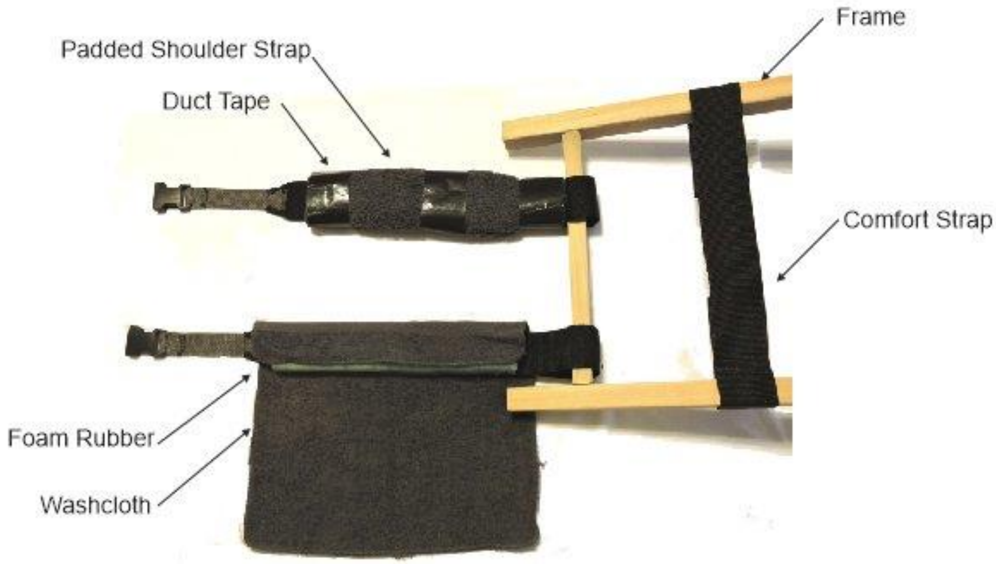
The comfort strap is installed around the two vertical members of the pack frame, with the elastic away from the person's back. The idea is to put it at a height which will correspond to the apex of the curvature of the spine, helping to hold the backpack frame away from the back slightly.

The next pieces to make are the two shoulder straps. These are made of a combination of the 1" and 2" webbing, joining the two together, in the manner mentioned above. The 2" part of the strap will go towards the top, spreading out the contact with your shoulders. The narrow part will go towards the bottom, allowing you to adjust the fit.



Once the shoulder straps are sewn together and attached to the backpack frame, it's time to pad them. While you could technically use the backpack frame without padding them, carrying any weight on it would get uncomfortable quickly. So, we're going to do a very simple padding of the straps.

To do this, we're going to use some 1/2" to 1" thick foam rubber, whatever you have. I had some 3/4" thick sitting around in the attic, which came out of a mattress that we had to dispose of. I cut the piece I was using into strips; some 2″ wide, for the shoulder straps and some 2-1/4″ wide, for the belt. You'll need one piece of foam for each shoulder strap and two for the belt. Cut the 2″ wide strips so that they are just a little shorter than the width of your washcloths.



Rather than take the time to sew the pads onto the shoulder straps, I used one of the all-purpose repair materials, duct tape. Part of this was to save time and part was to make it easier to take the shoulder pads apart and replace the foam rubber, if needed.

To attach it, lay the straps out, inside up, laying each across a washcloth, and lay one of the foam rubber strips on top of it. Then wrap the washcloth around the strap and foam rubber together, several times, using the whole washcloth.

This can now be taped together, by wrapping duct tape around the washcloth at both ends and in the middle.

Make sure that the end of your tape is on the outer side of the strap, and not the inside (the side with the foam rubber on it). If it is on the inside, then rubbing against your body could cause it to start coming undone.

Since we are starting with a pre-made belt, all that is needed is to add the padding. We will be adding three pieces, one across the back of the belt and shorter ones over each hip. In addition, we will be adding paracord ties, for attaching the belt to the frame.

If your washcloths are the same size as the ones I bought at the dollar store, then they will fit between eyelets on the belt. Mine spanned the space of five pairs of eyelets, ending just between the outermost pairs of those five. That worked out perfectly, giving me the maximum possible padding. As with the shoulder straps, the foam rubber was cut just a little shorter than the washcloth and the two were attached to the belt with duct tape.

In addition to the padding on the back of the belt, you'll want to add padding over the hips. I ended up folding the washcloths in half and using a shorter piece of foam rubber. I'd recommend making these pads as long as you have space for, so that as much as possible of the belt is padded. All you need to do to adjust the size is fold the washcloths to the right length and cut the foam rubber to fit.

Two pieces of paracord are threaded through the eyelets on the belt, allowing it to be attached to the frame. When you cut the paracord, it will need to have the ends fused, just like the webbing.

However, the eyelets are not very big. So, the end that is going through the eyelets will need to be formed into a point, while it is still melted.

You can do this with your fingers, but there is a chance of burning them. Using work gloves allows you to use your fingers, while offering them some protection.

- Attaching shoulder strap and belt to wood backpack frame.
- Attachment to the metal frame is accomplished the same way.

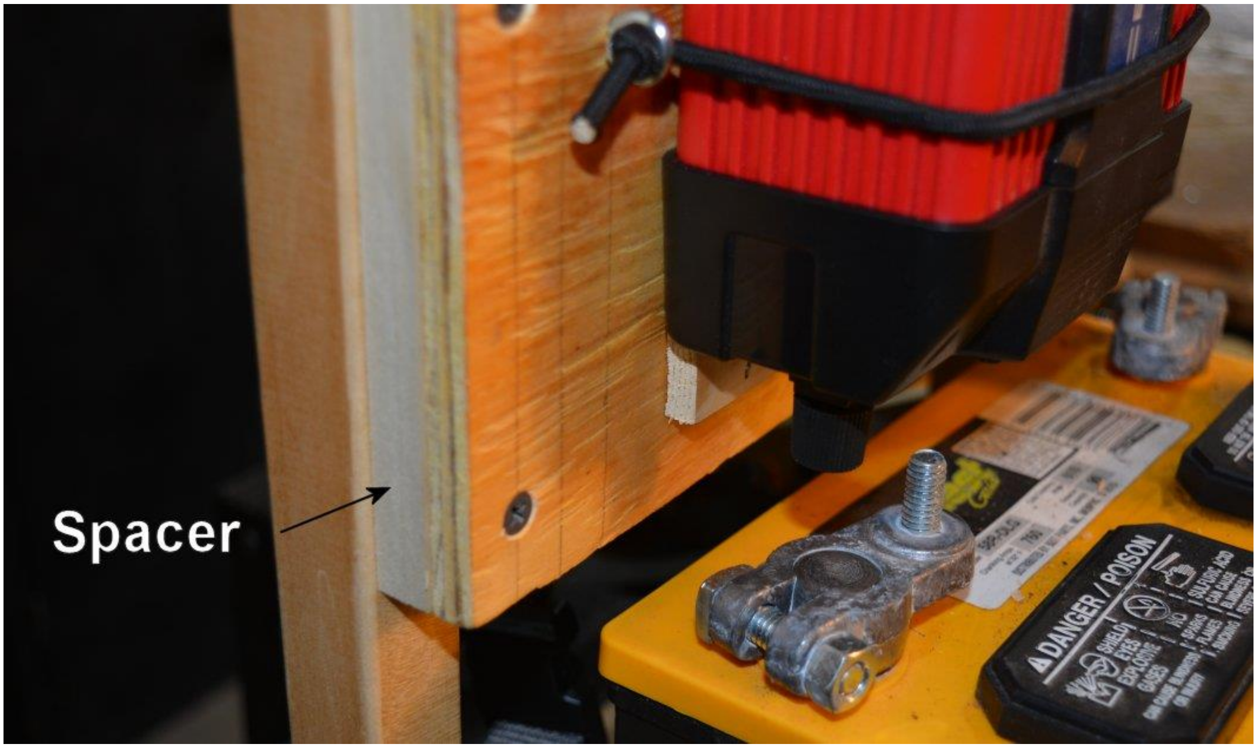
Paracord will hold 550 pounds of weight. So, even though this looks like some rather flimsy cord to hold the weight of the pack, I assure you that it is sufficient. The only way you could end up having a problem is if you left a burr in the hole in the bracket and wear through the cord.

Mounting Everything to the Frame

With the frame done, it's time to mount everything to it. This is more or less the same, whether you've decided to build the wood frame or the metal frame. Other than the spacers, the main difference between the two is whether you're going to be drilling through steel or wood and what type of hardware you end up using.

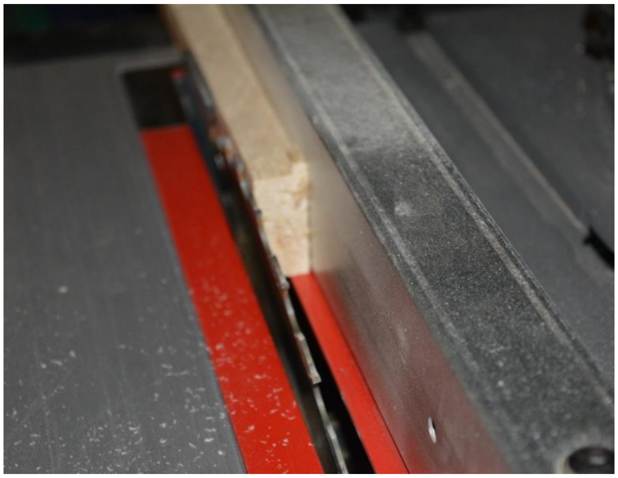
The control panel I made for the basic unit is not wide enough to span the vertical bars on the backpack frame, so we're going to need a new one. This one will need to be the same width as the backpack frame, so be sure to measure your frame to know the exact dimension. I ended up cutting a scrap piece of plywood off to be 14" long to fit the wood frame.

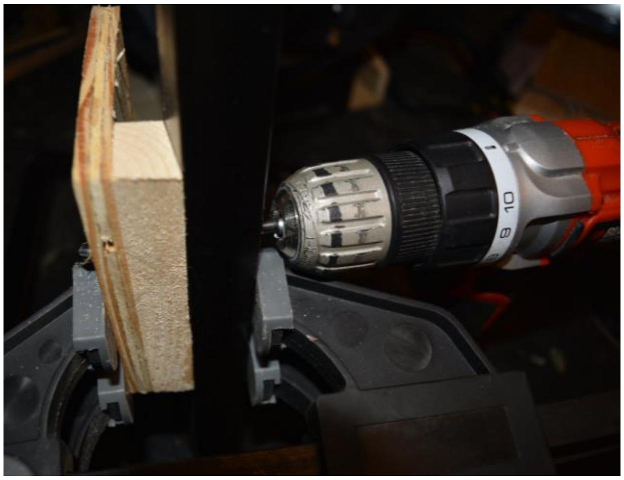
It helps to add spacers behind the backpack frame. Otherwise, the control panel will probably end up touching your back. But by adding a mere 1/2" of space between it and the frame, you eliminate that problem. These spacers can be cut from the leftover material from the shelf bracket, if you made a wood frame. Clearance holes should be drilled through the spacer, so that when you screw the control panel to the frame, the screws don't have to cut through the spacers.



Since the metal backpack frame has angled side bars, the spacers are going to need to be a little different. They will have to be angled, to match the angle of the frame. That way, the plywood backing board can be parallel to the plane of the frame.

This is actually extremely easy to do, if you have a table saw. We've already established that the frame is at a 10 degree angle. So, all we have to do is set the blade on the table saw to 10 degrees and rip a piece of 3/4" thick scrap. Then, the angled piece of scrap can be laid flat on the table and ripped again to make it 1" wide, this time with the blade set to a zero degree angle.





The other little trick is drilling the holes for the mounting screws. Since the metal frame is harder to drill than the wood backing board or spacer, start by drilling a clearance hole for the screw, through the frame. Then, clamp the wood backing board and spacer in place securely. As you can see in the photo below, I used two clamps. With it clamped in this manner, it's simple to drill through the wood from the back, even though that's drilling into the angled face of the spacer. The metal frame ends up working as a template.

While the hole will be at an angle going through the wood, requiring that the nut on the back of the screw be at an angle, that won't be a problem. Simply tighten the screw enough to pull the nut into the soft plywood, then cut off any excess screw length, as we did before.

The solar charge controller and voltage inverter mount to this backing board, just as they did in the basic unit. The only real difference is that the battery isn't mounted to it. That will require re-making your wiring to match this configuration, rather than what we used in the basic unit. But the wiring itself is essentially the same thing. We'll discuss in the next section what we are going to do about the battery.

MORE BATTERY CAPACITY

The original battery we used for the basic Backpack Electricity unit was a 7 aH (amp-hour) lead-acid battery. This is enough for small amounts of use, such as charging cell phones. But if you're going to want to use the Backpack Electricity unit to provide power for larger things, you're going to need to increase its battery capacity.

Remember, it's the battery which is providing the power that you are using, not the solar panels. The solar panels are there to charge the battery. This allows you to draw much more power out of the battery, than the solar panels can provide, at least for a brief period of time. How long that time is will depend on the battery capacity you build into your Backpack Electricity unit and the number of solar panels you are using to charge it.

One of the easiest ways of increasing the capacity of the Backpack Electricity unit is to change the battery, replacing it with one which is more powerful. Ideally, this means buying and installing a deep cycle marine battery, which can be purchased at your local auto parts store or any of the big box stores.

Deep cycle batteries are not rated in amp-hours, like the battery we used in the basic unit; they are rated in "reserve capacity." This is the amount of time that a battery can supply 25 amps of power, before its voltage drops below 10.5 volts, which is considered a dead battery. These batteries will range anywhere from about 60 minutes of reserve capacity, all the way up to 240 minutes of reserve power. To put that into amp-hours:

Reserve Capacity	Amp-Hours
60 min.	25 aH
90 min.	37.5 aH
120 min.	50 aH
150 min.	67.5 aH
180 min.	75 aH
210 min.	87.5 aH
240 min.	100 aH

You're better off if you can buy a battery with side posts, but deep-cycle batteries with side posts are few and far between. They typically come with top posts. But sometime the top posts have a threaded post alongside them. If not, you'll need to buy a pair of top post adapters as well. These come in two styles one with a stud to put ring terminals on (shown) and the other with a threaded hole to put a bolt in the end (such as the normal bolts used with side posts).

When attaching ring or spade lugs to a stud or screw, always put a washer between the ring terminal and the nut or screw head that is being tightened down on it. This will protect the terminal from being torn apart by the friction of the turning fastener.

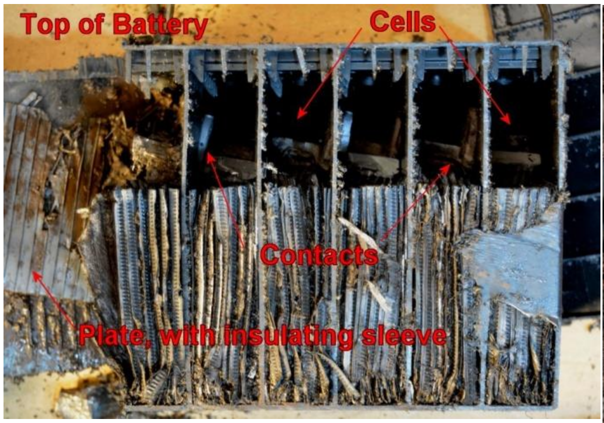
Rejuvenating Lead-Acid Batteries

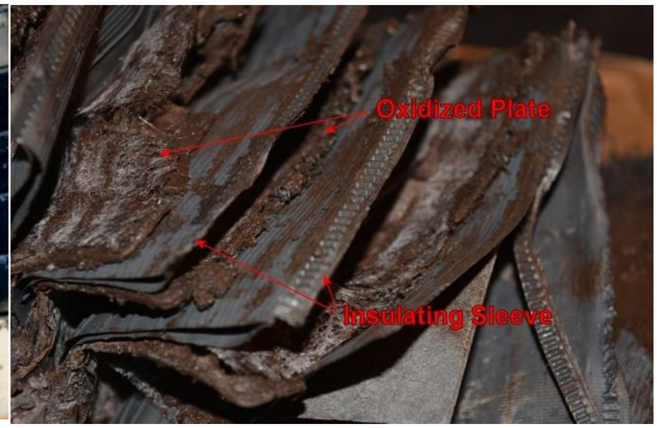
You can save a considerable amount of money on a larger battery for your Backpack Electricity unit, by opting for a used battery. People throw away batteries all the time, thinking that they are no good. Amongst these, we find a lot of lead-acid car batteries, which can actually be salvaged.

In order to understand this, we need to understand what makes these batteries go bad. Typically, when people get rid of a car battery, it's because the battery won't start their car. They don't understand why, they just know they can't start their car. Either it doesn't produce enough voltage or it can't hold a charge. So they replace it.

In normal operation, the alternator in the car provides enough electrical power to run everything, as well as recharge the battery. All the battery is needed for is to start the engine and to provide power when the engine isn't running (such as to use the radio). In fact, once the car is started, the battery can be disconnected and the car will continue running, if it has a good alternator.

Ok, so we have two different problems with these batteries, but they are both caused by the same thing. That is, damage to the lead plates. This damage comes about as a normal part of the operation of a battery, as it cycles between charging and discharging.





As you can see in the pictures of a dissected car battery above, the battery's plates suffer a lot of damage during use. But these plates can often be salvaged, allowing the battery to be used much longer. Here's the secret - the oxidation of the lead is only on the surface; not throughout the thickness of the lead plates. So, if the surface of the battery's plates can be rejuvenated, the battery will continue to accept a charge and make electrical power available when needed.

This procedure doesn't work with all batteries, but it works with most. The battery in the pictures above is actually beyond the point of salvage. About all that can be done at this point in time, is to take it to the auto parts store for recycling. But as long as a battery will still charge to about 10.5 volts, it's salvageable.

Here's how you do it.

To start with, let's make sure that the battery isn't really still good. There's no sense rejuvenating a battery that doesn't need it. Most car battery problems aren't actually the battery, but oxidation on the battery posts. So, before removing the battery from the car, disconnect the battery cables from the battery posts and clean the connectors and the posts with a battery post cleaner. It doesn't matter if the battery is a top post or side post battery, the same thing goes.

The second thing to do is to check the acid level in the battery. If the battery has caps over the cells, simply remove the caps and check the fluid level inside. If you can see fluid, the battery has enough. But if you can't, then that could be the problem. Fill it with distilled water. Don't use tap water, as it will contain some chlorine and mineral content, which could reduce the life of the battery. Recharge the battery and see how it does.

Assuming that those two steps didn't work, but you have a battery that provides 10.5 volts, you've got a prime candidate for rejuvenating. Clean off the top of the battery, removing any dirt, metal shavings and grime. This is to prevent this dirt from ending up inside the battery, where it can cause damage.

The next step is to remove the battery acid by simply pouring it out. Be careful with this, as it is sulfuric acid and can burn your skin badly. It can also destroy clothing, metal workbench tops and a lot of other things, so be extremely careful with the acid. Be sure to wear clothing that you're not worried about damaging or a shop apron over it to protect your clothing. Also wear rubber gloves and goggles to protect yourself. When pouring, tip the battery away from you, so that if the acid splashes, it hopefully won't splash onto you.

The acid you've removed from the battery can be neutralized by adding common baking soda (sodium bicarbonate). Since this is a base, it naturally counters the acid, bringing it to a pH of 7.0 (or at least near 7.0). To be sure that you've added enough baking soda, it's a good idea to check the pH with pH test strips. Once neutralized, the former acid can be thrown out in your yard.

We're going to replace the battery acid with a solution of Epsom Salt. Normally used for the treatment of sore muscles and sprains, Epsom Salt contains magnesium and sulfate, which is why it can be used to replace the sulfuric acid in the battery. However, we need a supersaturated solution. So, we're going to have to use water that has been heated to 150ºF.

Heat three cups of water on the stove in a normal pot. The Epson Salt won't damage cookware and is not poisonous. So you don't have to worry about destroying your cookware by using it to make your Epsom Salt solution. Once the water has reached a temperature of 150ºF, add one cup of Epsom Salt, stirring it until fully dissolved. If the water is still cloudy, it hasn't finished dissolving; continue stirring until the water turns clear again.

The Epsom Salt solution now needs to cool to room temperature, before it can be added to the battery. Once cooled, pour it into the holes, using a pitcher or measuring cup, filling each of the cells to a point just below the holes themselves. Make sure that the plates are fully covered.

The battery is now reconditioned. Place the caps back over the cells, but don't put them on tightly. Recharging the battery will cause the solution to outgas, building pressure in the battery, if the caps are on tightly. It's better to wait until the battery is fully charged before putting them on.

The battery should be trickle charged, not fast charged. A 2 amp charge rate is ideal. If you have one of the newer automatic chargers, this might be hard to accomplish, as not all of them allow you to select a charge rate. But if you have one of the older ones, there should be a switch and amp meter, allowing you to select the charge rate. At 2 amps, the battery will need a couple of days to fully charge, but it will be better for the battery.

Once charged, check the voltage of the battery. It should read somewhere between 12 volts and 12.5 volts, once the charger is removed. Allow it to sit for a day and check it again, to ensure that the battery is holding a charge. If it is, your battery is ready to reinstall in your car or use in your Backpack Electricity unit.

Change Battery Type

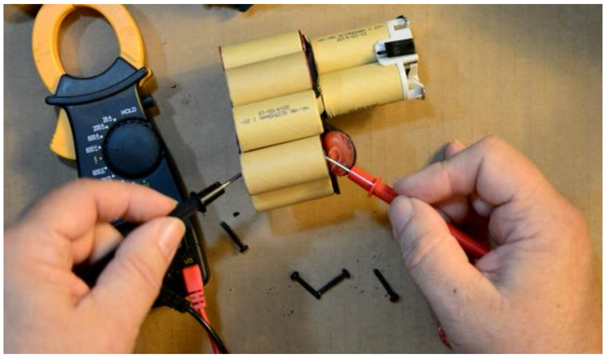
The big problem with using these deep-cycle lead-acid batteries is their weight. Some of the higher capacity ones range over 50 pounds, which is a lot to carry on a backpack. But lead-acid batteries are cheaper than any other type of rechargeable battery currently on the market.

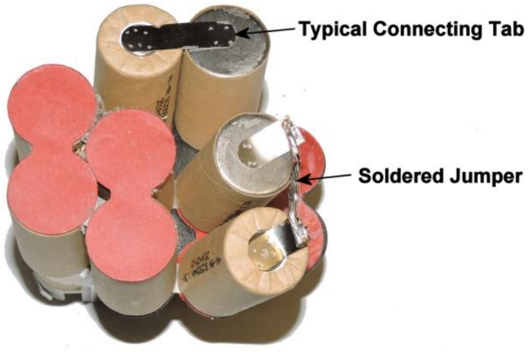
You'll have to decide for yourself what sort of rechargeables are best for you, based upon your needs. Basically, you're looking at a tradeoff between cost and weight. The more storage capacity per pound of battery, the higher the price. To use lithium-ion batteries, you're looking at spending two to three times what you'll spend on a lead-acid battery.

There is one other option; something that could save you money, if you have the right contacts. That is to salvage bad battery packs from cordless power tools. Building contractors have to replace these regularly and if you know any contractors, you might be able to get them to send some of their old battery packs your way.

The thing that most people don't realize about these battery packs is that they are actually made up of a number of separate batteries, usually soldered together with tabs. When they go bad, it's not all the individual batteries that go bad, but one. That one can be identified and removed, leaving all the rest of the cells intact.

On the chart earlier, I showed you that Ni-Cad and NiMH batteries provide 1.25 volts of power per cell, while Li-Ion provides 3.6 volts of power. So, a 14.4 volt NiMH or Ni-Cad battery pack is going to contain 12 cells, of which only one is probably bad. You can tell which one by individually checking their voltage with a multimeter. They will all probably read about 1.25 volts, except for one, which will be quite a bit lower and may even read zero. That's the bad one.

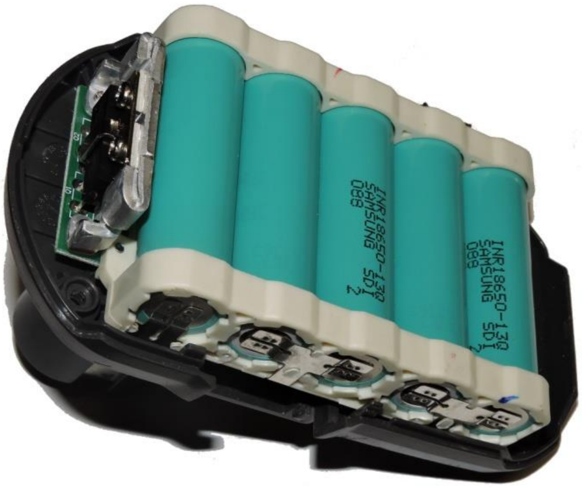




In this case, I removed two cells from a 14.4 volt pack (which actually produces a bit more than 14.4 volts), leaving me with 10 cells, which will produce 12.5 volts. Since I am looking for a nominal 12 volts for my power supply, that's perfect. Of course, this will vary, depending upon the type of batteries in the pack and the voltage. Older tools will use Ni-Cad or NiMH batteries, but newer ones will use Lithium-Ion.

Please note that I am soldering to the tabs and not directly to the batteries. That's mostly to reduce the heat exposure to the batteries. These are heat sensitive, especially to high heat. Soldering to the tabs reduced that risk. Besides, removing the tabs is difficult, so it's not worth the trouble.

Since Li-Ion batteries are 3.6 volts, there will be less cells in a battery pack. Typically, a 18 volt pack will have 5 cells, not the 12 found in the pack above. The Ryobi 18 volt (left, below) and Black & Decker 20 volt (right below) Lithium-Ion battery packs below are almost identical, both with 5 cells in them.



Notice the adhesive still attached to the Black & Decker battery pack on the right. This is similar to the adhesive foam mounting tape we used for assembling the solar panel. You may find that you have to cut or tear such adhesives to remove batteries. You may also have to cut the plastic holders (not referring to the cases here) that you see in the photos (white for the Ryobi and black for the Black & Decker), which hold the batteries together. But, to get cheap batteries, it's worth the trouble.

If we remove one cell from these battery packs, we end up with 14.4 volts, which will work for our purposes. However, removing two drops the voltage down to 10.8 volts, which isn't enough. In that case, we'd need to take batteries from more than one battery pack and connect them together.

The one potential problem with Lithium-Ion batteries that you need to be aware of is that they are more sensitive to heat than other types of rechargeable batteries. If you look back at the photo of the Ryobi battery pack, you'll see that it has some electronics on the left end. This is to control the charge rate. You will need to be sure to include this piece, when you put your salvaged battery packs together.

The one other advantage of Li-Ion battery packs, as compared to other types of rechargeable batteries is that they provide full voltage up until the time they are dead. Other rechargeable battery types start out higher than their nominal rated voltage and the voltage drops all the way through the usage cycle, until they reach a point where they can no longer power the device you are using them with. This is most noticeable with cordless power tools, which will slow down as the battery gets weaker.

Some people do not like this feature of Li-Ion batteries, as it can leave you suddenly without power. But if you monitor your power usage, this shouldn't be much of an issue. On the positive side, this makes it possible to use any devices you connect to the battery longer, as the battery will literally give you all it's got.

The salvaged battery packs can be connected together in parallel (positive to positive and negative to negative), increasing their capacity. In this way, we can ultimately have as much battery capacity as we want or as we can find batteries to salvage. We also end up with a much lighter battery pack, than what we had with the lead-acid battery.

Installing Li-Ion Battery Packs

If you don't have any friends who are contractors, don't feel bad; I don't either. Even so, you can still use Lithium-Ion batteries, you'll just have to buy them. I did some looking around, and found that I could buy Li-ion battery packs on eBay in a variety of different sizes. The particular battery packs I found were intended for use with surveillance cameras. I bought battery packs made for use in Europe, rather than the U.S. because I was able to buy them cheaper and I wasn't going to use the charger anyway.

These are rather simple, plain battery packs, shipped from China. They have two connectors on them, a male and a female. The female connector is intended for use with an included voltage charger. The male is for providing power to the surveillance camera.

I settled for a 12000 mAh battery pack, the same as 12 amp-hour. Three of these gave me 36 amp-hous, a similar battery capacity to what I had with the car battery. However, rather than weighing 35 pounds, my three battery packs weighed less than 3 pounds.

It's a bit hard to tell how the 90 amps of reserve current that the car battery has, compares to the 36 amp-hours that the Li-Ion batteries have. In order to get an accurate comparison, we need to convert the rating of one to the other. Car batteries are rated in "reserve current," but we're working in amp-hours. To change the 90 amps of reserve current we have in the car battery to amp-hours, we need to multiply it by 0,4167. That gives us 37.5 amp-hours.

One thing I noticed right away, when I got my battery packs, is that the wires for these battery packs are much smaller than the wires we've previously used. What that means in practical terms is that if the voltage inverter tries to draw a large amount of current out of one battery, it will burn the wire. So, it's a good thing that I'm using three batteries. In fact, it would be better if I was using five batteries. That way, the current can be drawn evenly from the batteries, keeping any particular battery or its wiring from being overloaded.

While the battery packs have two connectors on them, electrically they're really the equivalent of one connector, since they connect to the same place inside the battery pack. That works out well for us, as we're going to cut the longer lead off and use it to connect the battery packs together.

The lead that was cut off needs to be sealed, to prevent it from shorting out. To do that, I've simply put a small piece of heat-shrink tubing over the end of the wire, heated it, and then crimped the end together with pliers. This gives me a nice waterproof electrical cap, which is not likely to come off. If I had used electrical tape instead, it would eventually come off. However, I did use electrical tape to physically connect the battery packs together.

The three positive leads (red) from the three battery packs are soldered together, as well as the three negative leads (black). When I cut and stripped each set of leads, I staggered their length, making the red wire 1/2" longer than the black. What this did for me is protect the wires from touching and shorting out, while I was working on them.

The three positive leads are connected to the positive lead of a waterproof connector and the three negative leads to the negative lead of the connector. Since I'm using the same sort of waterproof connectors that I am using for the solar panels, it's necessary to differentiate them, so that the wrong connector can't be connected to the wrong place. This is easily done by using the opposite side of the connector. So, on the batteries, the positive lead is the male lead and the negative is the female. On the solar panels, it's the opposite.

With the wires soldered together, as shown in the picture above, I plugged them into the battery packs and then covered the soldered connections with heat-shrink tubing to protect it from the rain.

These batteries are connected to the Backpack Electricity unit much the same way the others were. The only differences are that the connectors used for the batteries are of a different type, and the main junction is at the voltage inverter, instead of at the batteries. Due to using the waterproof connector for the batteries, it's really not practical making the main junction at the battery, so I've moved it. Since this is the same point electrically, it won't affect the function at all.

Once again, there are a number of different ways in which we could mount the battery. I've decided to mount it the same way that the voltage inverter is mounted, holding it in place with bungee cord material, running through eye-screws attached to the shelf on the backpack frame.

This is one of those things that doesn't need to be done all that accurately. Simply locate the battery pack where you want it and mark locations for the screw eyes to be installed. You'll want them a little bit away from the battery packs themselves, so that there is room to maneuver the pack into position. I put mine 1/2" away.

While I centered my battery pack, you may choose to put yours off to one side, so that you have room to carry other things on your backpack frame; or you may choose to use eight or ten batteries, in which case, you'd probably be better off running them perpendicular to the frame, so that they would all sit on it. A lot depends on the batteries you choose to use.

Drill pilot holes for the screw eyes and insert them as far as you can. If you have trouble installing them, you can either use pliers to hold them or run a screwdriver through the eye for leverage.

I am using 1/3" bungee cord material that I bought from my local Army surplus store. However, you may not have ready access to that. If you don't, buy an assortment pack of bungee cords. Most now come with 12" miniature bungees in them. They are ideal for this sort of application. I also keep some on my backpack, for strapping extra stuff like coats onto it.

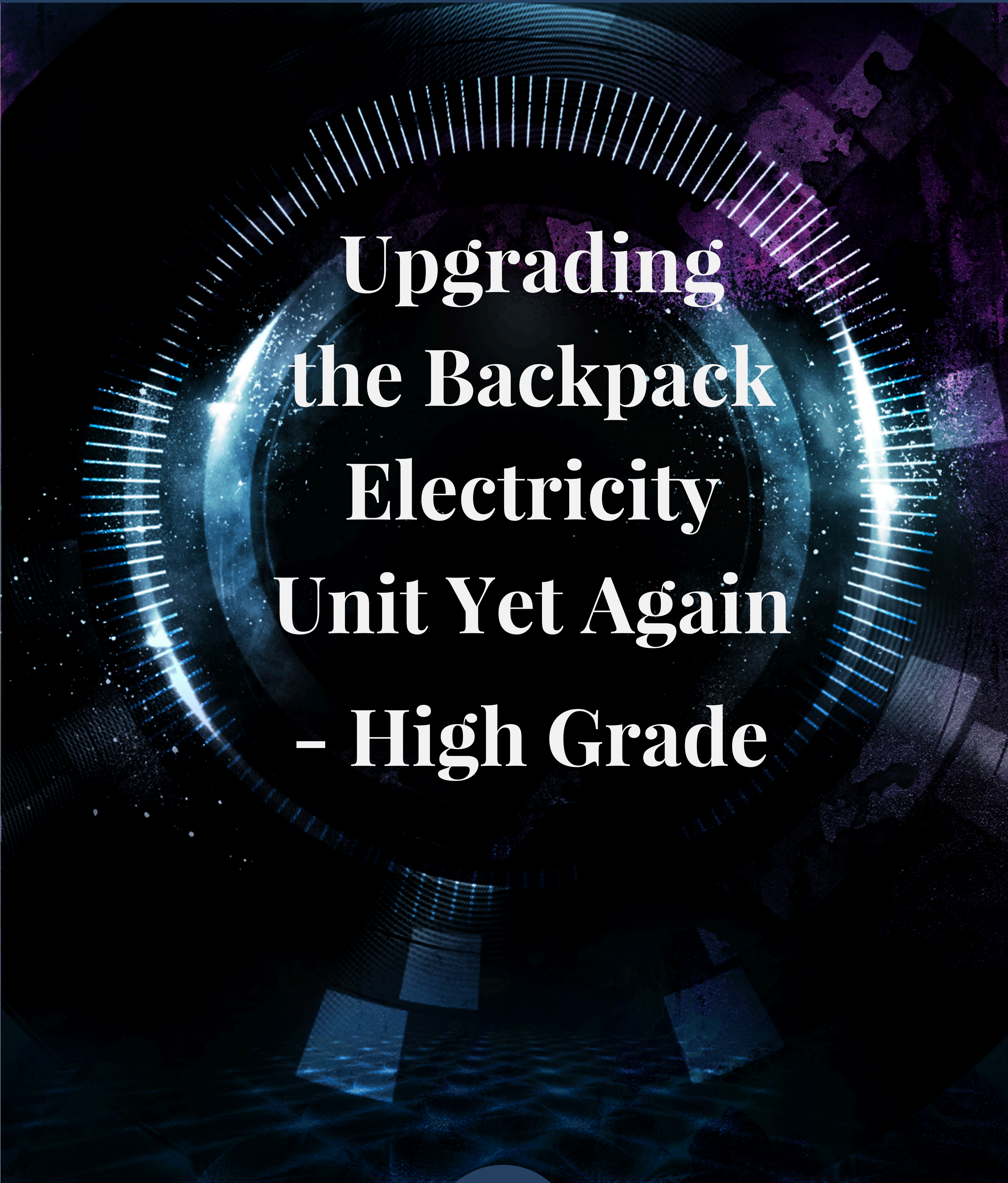
Looking back at it, I would have been better off cutting the connectors off of both leads and tying the wires together. That would have given me a lead that was twice the size and able to carry twice the current. But as I've already done it this way, I'll keep it this way.

MORE SOLAR PANELS

Finally, the other upgrade you should consider making to your Backpack Electricity unit is to add additional solar panels. You can add as many as you want, up to the amperage limit of the solar charge controller you bought. I chose a 30 amp controller, which gives me the capability of quite a few panels. Since the cost difference between a 30 amp controller and a 10 amp controller is minimal, I decided it was worth the extra two or three dollars.

Always remember that your additional panels should be connected in parallel (positive to positive and negative to negative) to the ones we already have. This will allow the wattage of the panels to add, while keeping the voltage constant. The more panels you have, the faster your battery will charge.

If you decide to add additional panels later, there really isn't any problem, even if you didn't put enough connectors on the solar panel harness. All you have to do is splice into the existing cable, adding additional length and connectors.



Upgrading the Backpack Electricity Unit Yet Again - High Grade

As it is, the Backpack Electricity unit is very effective, but not perfect. And while perfection is something we never truly reach, there are a couple of other things that it would be good to do to the unit; things that we would find on a commercially manufactured unit that was designed for use in an emergency. Since we're trying to save ourselves from buying one of those expensive units, it only seems fair to make sure that we have all the features that they do.

Specifically, we want to add:

- Voltage meter to tell us how much power we have
- 12 volt power connectors to use with portable devices
- EMP shielding to protect the unit from a potential EMP attack

These additions will help make the unit more useful in an emergency situation. There are many pieces of camping gear that people carry along, which run off of 12 volts. Most modern portable electronics, such as our smartphones and tablets, charge off of 5 volts, via a USB charger. So, adding those connections merely makes sense. Your voltage inverter may have a 5 volt USB connection, but not all do.

The voltage meter may be considered to be unnecessary by many people, but I like knowing how much power I have available. That sometimes affects the decision about connecting a particular piece of equipment and using it, or not. When your power is limited, this could end up being vital information.

But the big addition here is the EMP shielding. An EMP attack is one of our country's biggest threats right now. Should one happen, it would most likely destroy the solar charge controller and the voltage inverter in your Backpack Electricity unit, along with all the other electronics it would destroy. Some voltage inverters would survive, because they have all metal cases, but not all of them come that way. However, once we get the shielding built and installed, the unit will be protected from that risk.

CONTROL & CONNECTION PANEL

Before building the EMP shielding, it makes sense to install the voltage meter and connectors. That way, they can be included inside the shielding. While these components are unlikely to be affected by an EMP, theoretically the wires from them could carry the spike to the solar charge controller or voltage inverter and damage them. So, by installing this panel within the area that will be covered by the EMP shielding, we avoid that possibility.

I'm going to use the scrap Plexiglas from making the panel for this. I could use some sheet aluminum, but I already have this and it's easier to work with than the aluminum is. But I'm going to have to bend it. So, to start, I'm going to need to build a bender for my Plexiglas.

Most plastics are easy to bend and Plexiglas is no exception. Basically, plastics fall into two broad categories, thermoset and thermoform. Thermoset plastics are plastic resins that are mixed together with a catalyst and then poured into a mold. Those are by far the minority; the rest are thermoform plastics. That means that they are formed by heating and melting them.

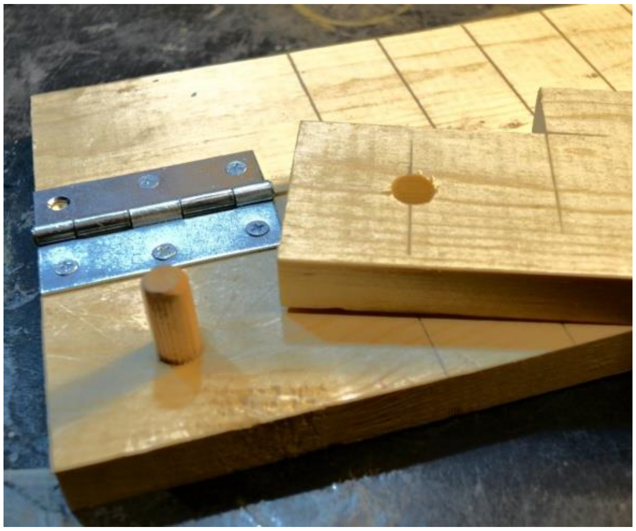
In order to bend plastic sheeting, like our Plexiglas, it's necessary to heat it enough to soften it, without heating it enough to melt it. There is a fairly wide range of temperature in which the plastic will form easily, but not really be melted. That's our target. We're going to use a heat gun, which I bought at Harbor Freight for about $15 as our heat source.

Commercially, thermoformed plastic sheeting is done on a device with a single wire or ribbon heater down the middle. The plastic is laid over this to heat, then bent when it is hot enough. However, these devices run from about $400 to over $1,000, much more than I want to spend.

Instead, I'm going to make a bender out of a couple of pieces of 1"x 4" whitewood and a couple of hinges. For the small amount of bending I'm going to do, this will work just fine. To make it, I cut a 6' long board in thirds.

Two of those will be hinged together to become the bender's table and the other will be cut to become the clamp bar.

The two table pieces are attached together with 3" hinges at both ends. You don't want any hinges in the middle, as that's where the plastic is going to be. The clamp board is shown below it. I cut the areas where the two hinges go out of this board, so that it could go all the way down flush to the table of the bender. My Plexiglas is actually thinner than the material of the hinges, so if I hadn't done this, it couldn't clamp the Plexiglas in place.



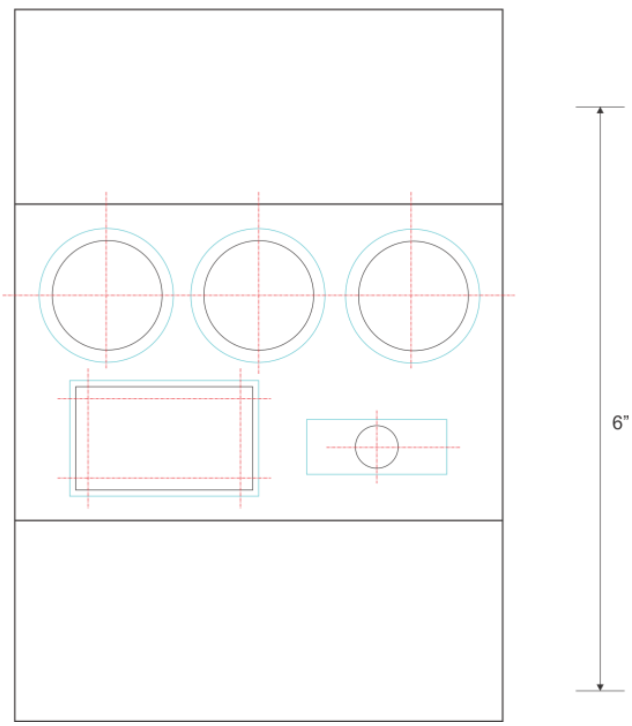
The other thing I did was to put a couple of alignment pins for the clamp bar. These are 1/2" dowel pins, the type that are used for attaching things together. I used a few of the same sorts of pins on the wood backpack frame, but those were 1/4", rather than 1/2".

In order to ensure alignment between the pins and the clamp bar

I clamped the bar and the table together for drilling. Then I glued the pins into the table. Since the dowel pins are slightly larger than 1/2" (I measured them at 0.515") I had to file the ridges down to ensure that they would go smoothly into the alignment holes on the clamp bar. You can't see it, but I also countersunk the bottom sides of the holes on the clamp bar, to make it easier to align the two pieces.

There was one final detail to make the bender usable. That was to use a pencil and square to draw a series of alignment lines on the tender table. Those allow me to align the pieces that I am bending, so that they don't come out crooked.

To make the panel, I cut off a piece of the scrap Plexiglas to five inches. This was based upon the room I had available on the control panel backing board. If you have a different solar charge controller than I do or have a different voltage inverter, you might have to adjust the size of the pattern to fit your space.



The pattern for my layout of the control panel is in the appendix. Just as you might have to adjust it for the space you have available on your Backpack Electricity unit, you might also have to adjust the holes in it if you have different sized components. So, before you start making it, you might want to check the dimensions of your various components.

If you can, it's a good idea to make the two "ears" of the "C" longer than what I show in the pattern, especially the one on the side that will be exposed. This allows it to also act as shock protection, so that fingers can't touch the electrical contacts on the back of the various components.

In order to make it easy to drill the holes in the Plexiglas, it's best to glue the pattern right onto it. I used a spray adhesive, applying it to the back of the pattern and then gluing it to the plastic film that comes on the Plexiglas. You can also use glue sticks, the same sort that elementary school kids use for craft projects with construction paper. Either way, gluing to the plastic film, rather than to the Plexiglas itself, makes it much easier to remove the pattern when you are done.

Mark the centers of the holes to be drilled with a center punch and then drill them out. The larger holes were actually cut with a 1-1/8" hole saw. The hole for the switch was drilled out in stages, starting with a 1/8" drill bit and increasing by 1/8" increments. The square cutout for the voltage panel meter is drilled in the corners, then cut out on a scroll saw, using a file to clean up the corners.

Make a final check of the fit of all the components before continuing on. You may need to file out some of the holes to enlarge them slightly, if your components aren't the exact size or you mis-measured. I needed to enlarge the holes for my 12 volt connectors, because they were just a little too large for the 1-1/8" holes. But since they weren't large enough for a 1-1/4' hole, I couldn't cut them out with the next size larger hole saw.

With the holes complete, the panel is now ready to be bent, using the bender I talked about earlier. Mark the bend points on the edges of the Plexiglas, with a permanent marker. Then you can remove the protective film and pattern. Don't try to bend the Plexiglas with the film attached, as the heat could fuse the film to the Plexiglas.

Lay the panel on the table, aligning the bend marks with the crack between the two boards and the side of the panel aligned with one of the guidelines you've drawn on the table. You'll want the part of the panel with the holes in it to end up under the clamp bar, when you apply it. Allow the ear to be on the part of the table which will be bent. Heat the Plexiglas along the bend line with a heat gun on high. Keep the heat gun moving back and forth, to heat evenly; don't keep it in one place.

The first thing you'll see when you heat the Plexiglas is that it will begin to hump upwards along the bend line. This is because the Plexiglas is hotter on the top side than the bottom side, causing the top to expand, while the bottom remains the same dimension. Watch this and wait for it to flatten out again. Once it does, give it a few more seconds of heat, and it should be ready for bending.

Be careful not to overheat your Plexiglas. Overheating will cause bubbling in the surface of the plastic, damaging the finish. This also makes the part more brittle, although that shouldn't really make a difference in this application.

Place the clamp bar onto the part of the table with the pins or clamp it to whichever part you've decided will be the stationary side of your bender. Put pressure on it, to ensure that it is holding the Plexiglas in place and lift the unclamped side of the bender's table upwards, forming a 90 degree angle. Please note that because the holes in the Plexiglas are close to the edge, proper clamping is necessary to ensure that the holes don't become oblong.

You may want to use a square to ensure that you actually have a 90 degree bend. I didn't and ended up overbending my panel slightly. That's not really a problem, but the project will come out neater if you bend it exactly.

Repeat the bending procedure for the other ear, taking care to ensure alignment and proper clamping. Allow the bent panel to cool before proceeding to do anything more with it.

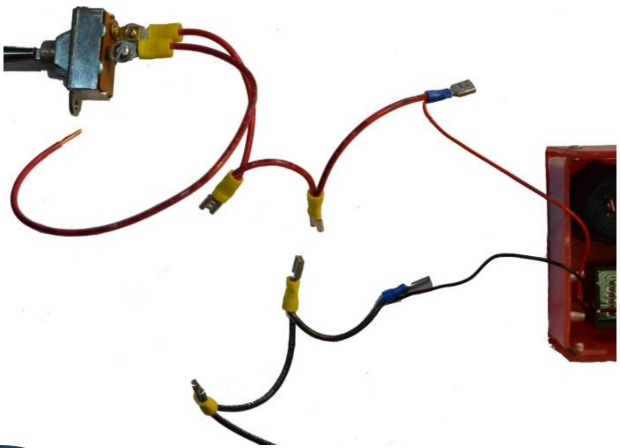
While the panel is cooling, you can make the side pieces. These are not absolutely required, but they add strength and act as guards so that your fingers don't touch the contacts and give you a shock. The pattern for the side pieces is in the appendix. Once bent, I glued and pop riveted mine to the connection and control panel, for extra security.

Please note that the Plexiglas I used for this is clear, as shown in the video of me bending the Plexiglas. However, to make it more visible for the pictures, I've painted it red. I don't recommend this, as enamel paint doesn't dry well on plastic. It was tacky when I took the pictures, and that's after sitting overnight.

I'm going to install:

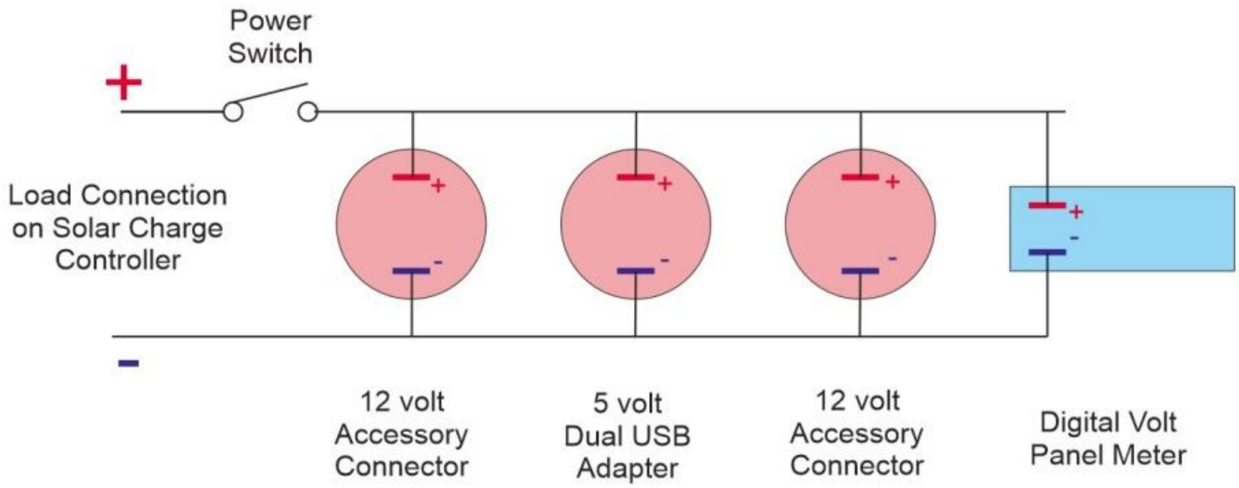
- 2 - 12 volt "cigarette lighter" connectors in the larger round holes
- 1 - dual USB connector (which also drops the 12 volts from the battery down to 5 volts)
- A voltage panel meter in the rectangular cutout
- A power switch in the small round hole

You might be better off installing the components, before the wiring or better off attaching the wiring and then installing the components. I ended up installing everything but the power switch before connecting the wiring. Since the power switch had screw posts, I couldn't connect to it well, once it was installed. Mounting everything else made it easier to work with.



I used 1/4" slip on crimp connectors, because that's what came with the sockets. Had those not come with it, I probably would have soldered the wires to the tabs. But the crimp connectors are easier to work with and provide a good connection.

As you can see from the photo above and the drawing below, this meant putting double wires into the crimp connectors. I was using 14 gauge wire, so to be able to do this, I had to step up the size of the crimp connectors to the 10-12 gauge size (yellow) in all cases, except the small wires coming from the voltage meter, which are 14-16 gauge (blue). There is enough slack in each of the segments, so that the wire can make a comfortable loop and not put any strain on the connection.



There is also an extra wire sticking out from the last slip-on connector in the black wire and from the power switch on the red wire. These will be connected to the "load" connection on the solar charge controller. The power for the voltage inverter bypasses this and comes directly from the battery, but the smaller load needed for these connections works fine through the charge controllers load lugs.

This means that the power switch is only going to turn on and off the 12 volt and 5 volt connections. It will also disconnect the power meter, so that the meter doesn't draw down the battery. However, the voltage inverter has its own power switch for shutting it down when not in us.

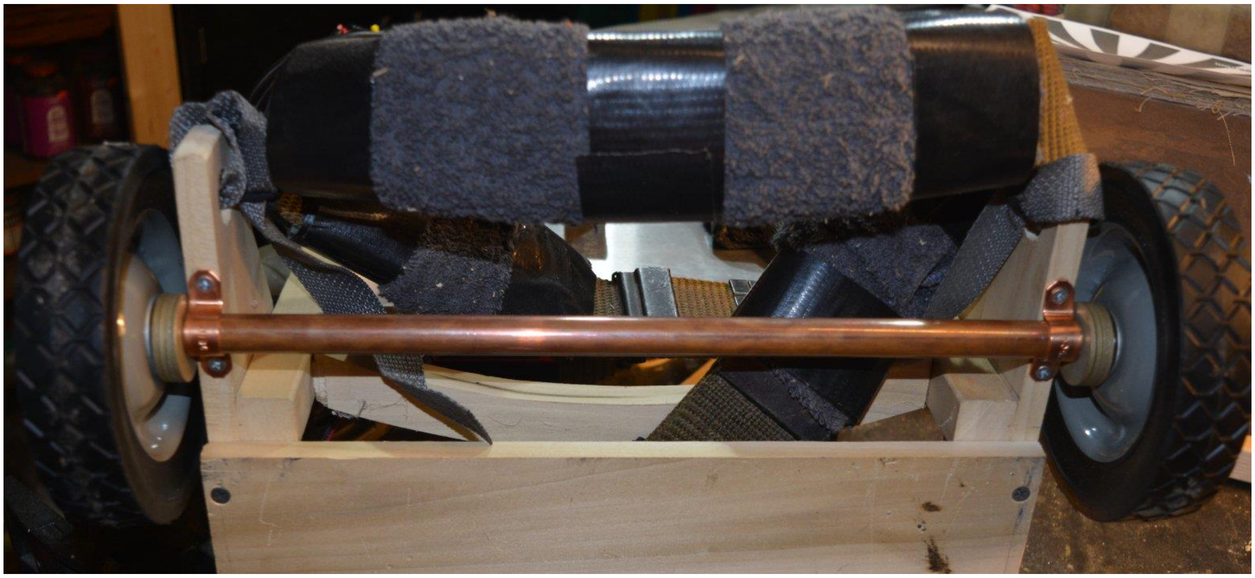
The connection and control panel can be mounted on the control panel backing board with screws, or a combination of screws and foam mounting tape. I drilled through from the back side of the backing board, into the ear of the connection and control panel, as I did not have any direct access to drill from the front side. I then installed the connection and control panel with #8 x 3/4" machine screws and nuts.

ADDING WHEELS

Two of the key ideas I've tried to incorporate into the Backpack Electricity unit are flexibility and portability. That's why I'm showing you various options for how to build it. Some may prefer the metal backpack frame to a wood one, but I personally prefer the wood one, as it is lighter.

Weight is always an issue in anything that is supposed to be man-portable; whether we're talking about a radio or something for backpacking. People pay extra money for low-weight backpacking equipment, simply so that they don't have to carry extra weight along with them. This issue becomes even more important when you take into consideration the possibility that the pack might be carried by a woman or child, who can't carry as much weight.

For that reason, I've decided to add an option for putting wheels on the Backpack Electricity unit. However, I don't want those wheels to interfere with its normal operation or the ability to use the unit as a backpack. Here's what I've come up with.



[Wheels installed on wood backpack frame; shown from bottom.]

There are a number of different ways of adding the wheels and so I looked at several. But I ultimately settled for the simplest design I could come up with. That consists of a pair of six inch wheels, mounted to a piece of 1/2" diameter all-thread as an axle. The axle goes through a piece of 1/2" copper pipe, which is held to the bottom of the Backpack Electricity wood backpack frame with normal 1/2" pipe hangers.

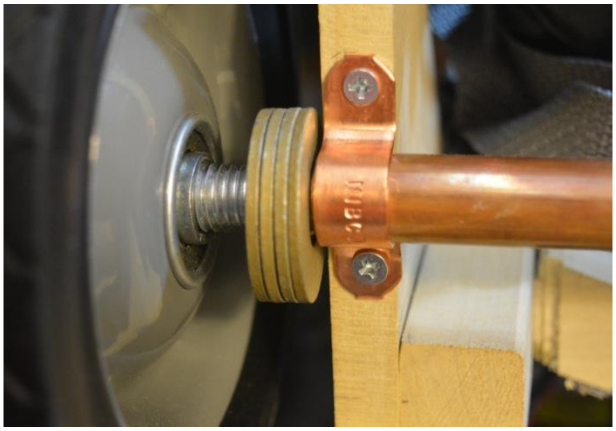
The one thing you have to watch out for in this design is spacing. I have aligned the wheels so that they are flush with the ends of the shelf bracket, on the belt side of the bracket. Mounting them flush like this allows the unit to be pulled easily, without the risk of the frame hitting the ground. At the same time, the wheels are out of the way, when carrying the unit as a backpack.

To mount it, I cut the copper tubing to the width of my backpack frame, which is 13-1/2" at this point. That made for easy alignment of the tube with the backpack frame. But then I found that I needed to space the wheels farther apart than a single washer would allow. So, I ended up putting four washers on each side of the tube, strictly for spacing.

I could have avoided using those washers or cut them to two, by making my copper tubing about 1" longer. However, there would always be problems with it shifting back and forth, especially when dragging the unit over uneven ground. About the only way to avoid those problems would be to solder the pipe hangers to the copper pipe (which does work by the way).

The wheels I bought have an offset hub, meaning that the hub is closer to one side of the wheel than the other. The closer side is to go towards the inside. This also helps reduce the amount that the nut on the outside protrudes. I've used nylon-insert nuts for this, so that they won't come loose.

Using nylon-insert locknuts makes it possible to tighten attach the wheels to the axle securely, without having to use excessively tight nuts. That's because it's the nylon which is causing the lock, rather than the metal-to-metal friction with normal nuts. While the wheels I bought had integral bearings, overtightening keeps them from turning freely.



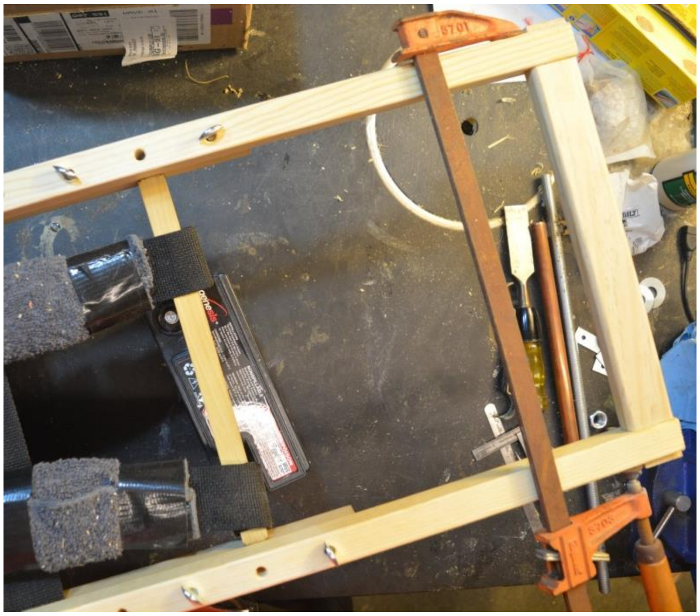
[Washers used for spacer. Wheel is out of place]

Tightening nylon-insert locknuts to both ends of a piece of all-thread is tricky, especially if you don't have any way of gripping the all-tread. I find that it works best to start them at the same time and tighten them equally. It takes more force to start the threading through the nylon section of the nut, than it does once the threads are through the nylon. So, by starting together, you'll be cutting those threads through the nylon on both sides, at the same time.

A Handle to go with the Wheels

Mounting wheels like this make it possible to move the Backpack Electricity unit around sort of like a hand truck, either pushing or pulling it. However, the backpack frame isn't tall enough to make it comfortable to move in this way. Since we want to retain flexibility, we don't want to make the frame larger, so we're going to need to attach a handle; preferably a removable one.

The handle I came up with consists of three pieces of wood. The two vertical ones are the same kind of 1" square dowels that I used for making the wood frame. For the handle itself (the part you hold), which runs horizontally at the top, I'm using a piece of 1"x 2" pine.



The three pieces form a U, as seen in the photo below. This shows the gluing of the pieces together. For that, the uprights are attached to the uprights on the wood backpack frame, ensuring that they have the right spacing. Then the crossbar handle is glued in place. A bar clamp holds it together while the glue dries. But, I'm getting ahead of myself.

We have the same problem in putting this handle together, that we had for putting the wood backpack frame together; that of not having enough wood to use most fasteners effectively. I've chosen to deal with that problem in the same way, using mortise and tenon construction.

Even so, this one is slightly different than the mortise and tenon I used for the frame itself. The major difference is that I need my mortise and tenon to be at the end of the wood uprights, because that's where my handle needs to be. So, what I've done is to cut a 1/2" wide slot in the uprights, for the 1/2" thick tenon in the handle to fit into.

To do this, I started by drilling a 1/2" hole in the uprights, centered 1-1/4" from one end. I then marked the width of that hole to the end of the uprights and cut it with a small back saw. After a little cleanup with a chisel, I had a perfect mortise.

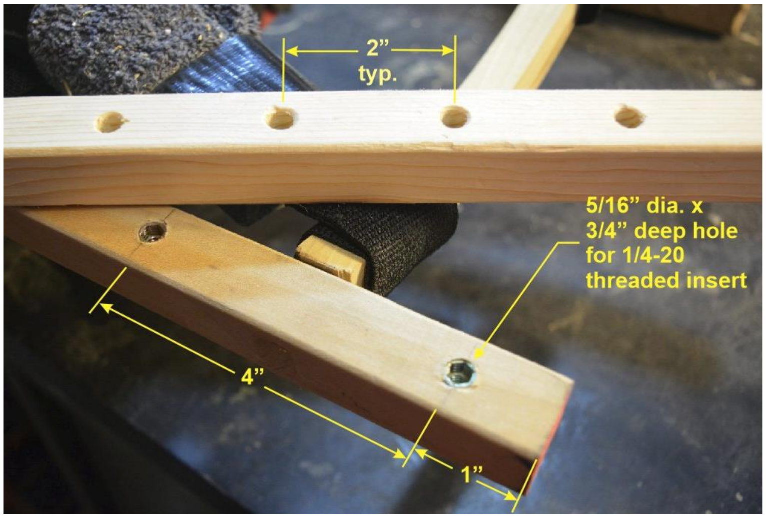
The tenons on both ends of the crossbar handle were just about as easy. Like here with the mortise, they were cut with a backsaw, after marking the dimensions directly on the wood. You'll notice in the diagrams, included in the appendix, that the tenon is offset. This allows the handle itself to hide the semicircle of the drilled hole, at least from the inside.

In the image below-left you can see the tenon sticking out past the end of the mortise. I glued it together this way and then cut it off flush, so that I wouldn't end up with the tenon being too short. In the image below-right, you can see the tenon and dowel cut off, and the hole from drilling filled with wood putty. The putty I am using (Plastic Wood) almost disappears into the grain of the wood.


You can also see in these photos that I've doweled the mortise and tenon joint together, giving it added strength. That way, even if the joint isn't tight, there's no way that it will come apart. The little bit of extra work drilling a hole, pounding in the dowel and cutting it off flush is worth the effort for the added strength it gives the handle.

The only thing we've got left at this point is to be able to attach the handle to the Backpack Electricity frame. This is simplicity itself. A series of holes are drilled in the uprights and threaded inserts installed in the existing frame uprights.

In order to drill the holes for the threaded inserts, without the risk of drilling through the dowel, simply wrap a couple of layers of masking tape around the drill bit. That makes an effective drill stop and can be easily removed once there is no more need for it.



By putting five holes into the uprights on the handle, while there are only two on the frame's uprights, I was able to make the handle adjustable for different height people, with a very minimal amount of extra effort. In order to maintain the adjustability, I'm using 1/4"-20 x 1-1/2" thumb screws to connect the two together.

EMP SHIELDING

Adding EMP shielding to your Backpack Electricity unit will ensure that you have electrical power even after an EMP, one of the most serious threats our nation faces today. It is widely believed that such an attack would take the electrical grid down for at least a year and maybe even permanently. Likewise, most electronic equipment which is not protected will be destroyed.

However, all it takes to prevent an EMP from destroying electronic equipment is to shield it with a Faraday Cage. This is nothing more than a metal container, which is electrically insulated from the electronics inside. Literally any metal will do; a metal trash can, a steel toolbox, a metal filing cabinet, or even a box made of chicken wire or metal screen. The metal doesn't have to be solid, just as long as it totally surrounds the contents.

From an electronics point of view, EMP is high energy, high speed electrons, flying through the atmosphere. In this, it is much like radio waves or lightning, but at a much higher potential. However, since it is much like high energy radio waves, it has to obey the same laws of physics that any electricity, like radio waves, has to.

Part of that is that metals are a good conductor of electricity; a much better one than air. So, an EMP will be attracted to metal... any metal. It won't pass through that metal, but rather, be absorbed and conducted by it. That's what a Faraday Cage does; it absorbs the EMP, preventing it from flowing through to whatever is inside.

You might think that lightning hitting a plane would be rather scary, causing the plane to malfunction and fall out of the sky. But it's actually not that uncommon an occurrence. That's because airplanes are perfect Faraday Cages, having an aluminum (metal) skin. So, when lightning hits the skin of the airplane, is conducted by the skin, passes around the outside of the airplane and continues on towards the ground, without affecting the airplane at all.

This is the same thing that happens when an EMP hits any Faraday Cage. While it might destroy anything outside of the cage, it can't touch what's inside. The only way it can touch what's inside, is if the electronics inside are electrically connected to the skin of the Faraday Cage. As long as there is some material that doesn't conduct electricity between them (air, plastic, wood, rubber, etc.) the EMP won't affect the contents.

So, to ensure that your Backpack Electricity unit survives the danger of an EMP, we need to encapsulate it in metal. Fortunately, we don't need to do this with the solar panels. While solar panels are damaged slightly by an

EMP, losing about 5% of their efficiency, they will still provide electricity afterwards.

We're going to make the EMP shield out of aluminum , due to its availability, light weight and ease of working with. While we could make it out of steel, that really wouldn't gain us anything, except more weight.

While we are making the EMP shield out of aluminum, there's something else you need to understand about radio waves, and how radio wave theory applies to EMP. That is, to radio waves, three wires running across the sky, like the three wires you see on a power pole, is a solid wall of metal, running from one of the outermost wires to the other. While I can't tell you exactly how far apart the wires can be apart and still appear like a solid wall to the radio waves, we can be sure that they don't actually have to touch.

What this means for you and I is that if we have cracks and openings in our EMP shield, they aren't going to destroy its effectiveness. That's great, as we need to leave a gap at the bottom, for the wires to run through. But we're okay in doing that, as not only will that look like a solid wall, but it's on the bottom side and the EMP will come from above.

If you can't find any other aluminum sheeting to use, you can use aluminum flashing, like what is used to form the valley on rooftops. Aluminum flashing is available at any building material's center. This is 31 gauge aluminum sheet, making it about 0.009" thick. That's a bit thin for my tastes, because it would be too easy to damage; so I'm using some 24 gauge aluminum sheet, that I bought from my local steel supply. It's 0.020" thick, a little more than double the thickness of the flashing.

Aluminum sheeting can be cut in the same way that we were cutting the Plexiglas for the solar panel, score it and break it. Actually, the aluminum works better for this than the Plexiglas did, with much less possibility of it breaking off at an angle. Just be sure to bend the aluminum away from the score first and then bend it back and forth a few times to get it to break.

In some cases, the patterns I have created for these parts might be a bit difficult to cut out. Take your time. If the aluminum sheeting gets a kink in it from bending it to get a cut to break, you can easily straighten out the kink by laying the part on your workbench and hitting the kink with a hammer or rubber mallet. The angled cuts on the tabs are probably what will give you the most problem; but these are necessary. They are what allow you to bend adjacent sides in the bender.

While bending works great for the larger cuts, like cutting the overall dimensions of the part or cutting out the back piece, the front and lid pieces have some fairly intricate cuts in the corners of the sheets, where the tabs are. I really wouldn't want to try cutting these places out by bending. In those cases, I recommend using tin snips or aviation snips.

Do not score any of the lines in the patterns that will be bent. Doing so would weaken the parts, possibly causing them to break, either when you try to bend them or while the unit is in use.

Sheet metal is usually bent in what is known as a "brake." However, we are going to use the same bender that we used for bending the Plexiglas, when we were making the connection and control panel. I've made a different clamp bar for it, with the edge close to the bend cut at a 45 degree angle. This allows me to bend two adjacent sides, such as two of the sides on the back piece. Without that angle cut, I'd only be able to bend opposite sides.

The new clamp bar is made out of hardwood plywood for added strength; although you could probably use 1"x 4" whitewood, like we did before. It also has to be clamped in place, because aluminum is harder to bend than heated plastic. I'm using a couple of C-clamps for this.

As you can see in the photo, the clamp bar also has a larger cut out for the hinge, both in depth and in width. This is to make it possible to make multiple bends together. Without that, the already bent adjacent sides run into the clamp bar when you're trying to bend the third and fourth sides of the lid.

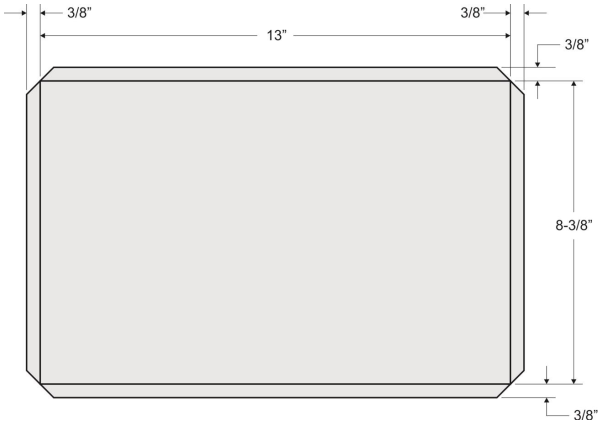
To bend the aluminum sheet, lay it on the bed of the bender, just like before and place the clamp bar on top, using the same dowel pins to align it. Clamp the clamp bar in place with the C-clamps and then recheck the alignment of the workpiece. It may move slightly while putting on the clamps. If it does, you'll need to loosen them up and try again. With the workpiece aligned and clamped, simply lift the back part of the bender's table to bend the aluminum cleanly.

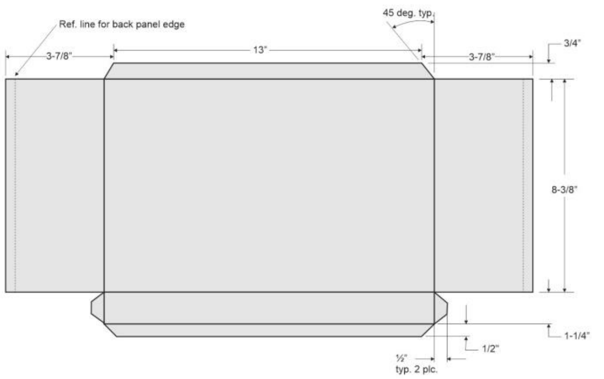
Please note that without the C-clamps, it's going to be impossible to get a nice sharp bend in your aluminum. What will happen is that the stiffness of the aluminum will push up the clamping bar, causing a rounded corner, rather than a sharp one. This could also allow the part being bent to slip, resulting in a crooked bend.

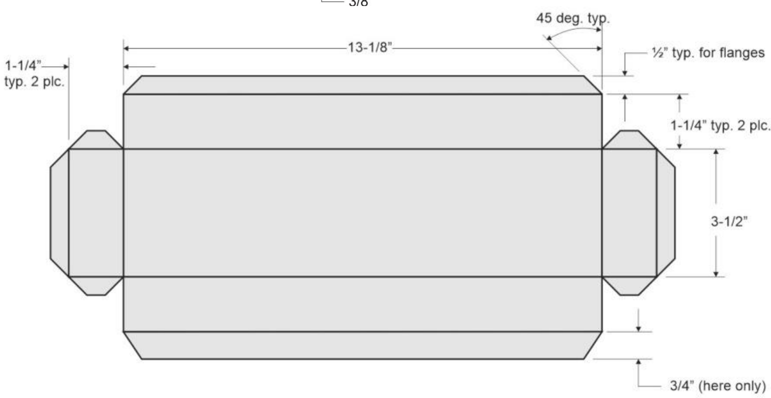
Another useful trick when bending aluminum on this sort of bender is to make your bend, then flatten the bend out most of the way by hand. This will leave the nice crease of the bend in place, while making it possible to put the part back in the bender for an adjacent, perpendicular bend. Once the second bend is made, the first one can be remade by bending the aluminum with your hands. It will come out clean, because you haven't disturbed the crease. However, if you try to do this repeated times, you will end up breaking the metal, just as we did when scoring it to cut it.

You can also use a hand-held sheet metal bender, called a "sheet metal seamer" to bend the aluminum. The problem with this is that the seamer is only 6" wide. So, it will not handle the wide bends we are making on our parts. This means that the bend will have to be done in parts, ending up sloppy. There is also a problem with the seamer's throat depth not being deep enough for all the bends we are going to make. However, a seamer is very useful for bending the small flanges which will be used for riveting the pieces together. It's also useful for finishing off the edges which are folded over, crimping them to make a neat edge.

You will find detailed drawings for the three parts you need to make out of aluminum sheet in the appendix. Please note that these drawings are based upon my Backpack Electricity unit, which is built to the dimensions shown in the drawings in the appendix. If you changed any of the dimensions in the process of making yours, you'll need to adjust the dimensions on the drawing accordingly.







Specifically, these drawings are based upon the backing board for my control panel being 13" long and 8-3/8" high. It is made out of 3/8" thick plywood. The edge of the plywood is referenced on the drawing for the front piece by a dotted line. I have also used the dimensions of the connection panel, as shown in the drawing in the appendix. Some specific changes you might need to make are:

- If your plywood is thicker than mine, you'll need to change the width of the flanges on the back piece and the width of the two ends (the ones with the dotted line to reference the backing board) in the front piece.
- If your backing board is wider than mine, you'll need to adjust the width of all three parts.
- If your backing board is higher than mine, you'll need to adjust the height of the main part of the back piece and the front piece, along with the tabs and ends.
- If your connection panel is higher than mine, you'll need to adjust the two ends of the backing front piece, as well as the ends of the lid.

Please note that the drawings for these three parts are not patterns, they are technical drawings. You'll need to draw the parts out on the aluminum yourself, with a pencil and ruler. Since the parts are larger than a sheet of paper, there was no practical way of fitting patterns into the appendix.

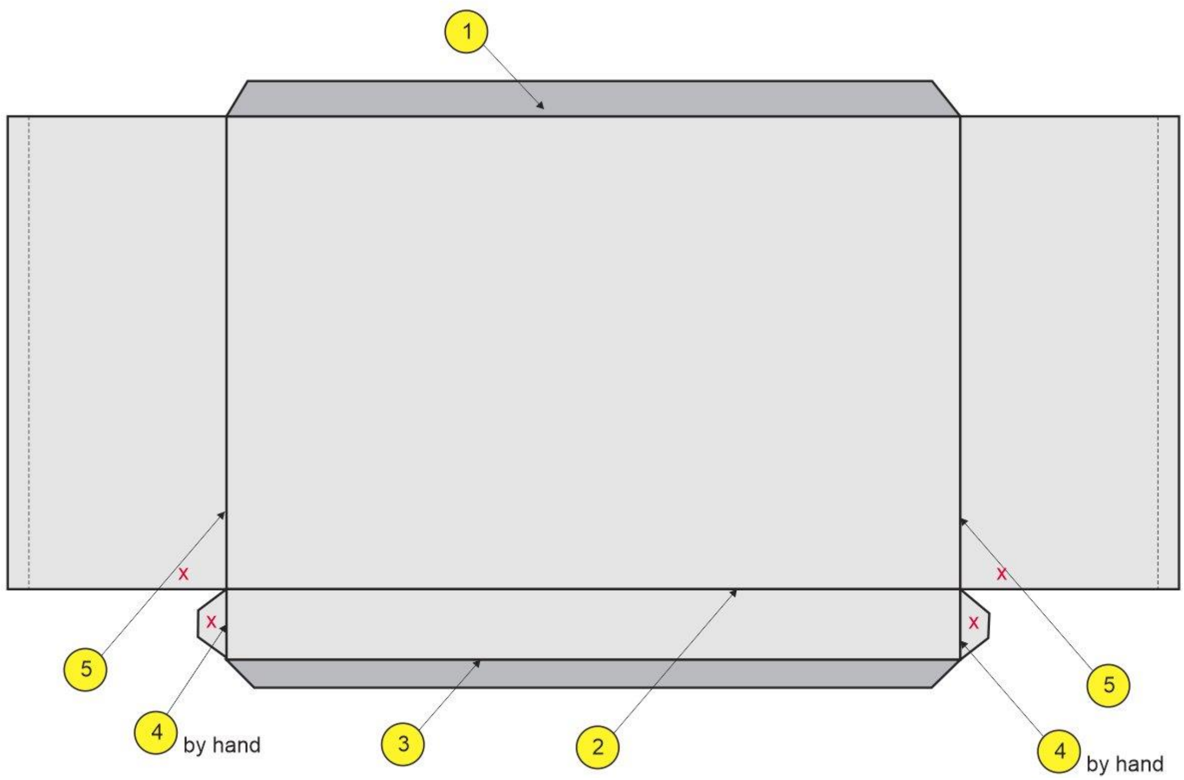
You may notice that the front piece and lid piece each have a lip that is 3/4" wide, rather than the 1/2" wide as the rest of the lips. This is not an error. These are wider because they are the support for the hinge that will be attached to the EMP cover. Without them being wider, the hinge would sit unevenly.

You can easily draw on the aluminum sheet with a pencil. Be careful though, as you can "erase" your lines by wiping over them with your hand. That's convenient if you want to erase them, but a nuisance if you don't.

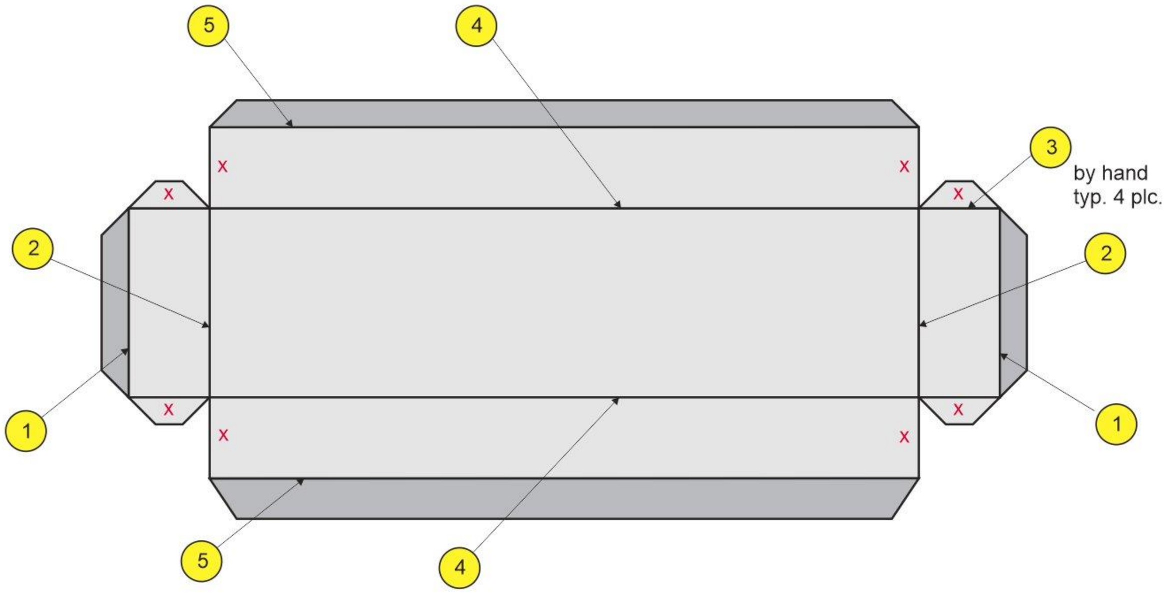
Double check all your dimensions before cutting, comparing them to your own Backpack Electricity unit. The old adage of "measure twice, cut once" is just as applicable here, as it is anywhere.

With the three pieces cut out, you're ready to move on to bending them. I'd recommend starting with the back piece, as it's the easiest and ending with the lid, as it's the hardest. The drawings below give you an order for making the various bends. I didn't bother supplying one of these for the back, as it really doesn't matter what order you make the bends in. While you don't exactly have to follow this order, it is one that I know will allow you to make all the bends.

Front

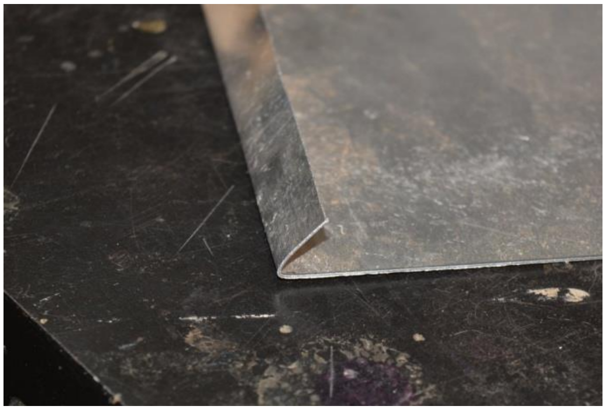


Lid

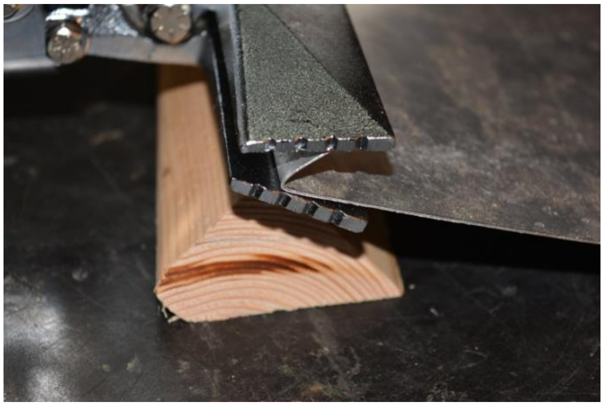


For both the front piece and the lid, there are flanges which are colored in a darker grey in the drawings. These are to be bent 180 degrees, not a simple 90 degrees like all the other lines. The bender will give you the first 90 degrees or a little bit more, then you will have to continue by hand. All you need to do is to bend the flanges by hand, a little at a time, until they are mostly bent. Then you can finish the bend with the seamer, fully flattening it.

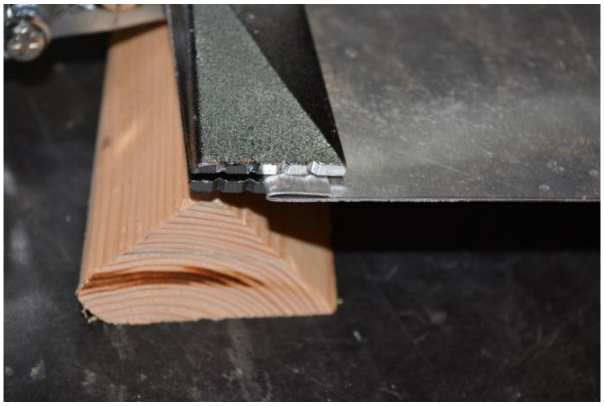
First the flange is bent to 90 degrees on the bender.



Then it is bent farther by hand, taking care to keep the bend even.



The seamer is then placed over the bend, ensuring that its full depth is within the jaws of the seamer.



After flattening with the seamer you have a perfect rolled edge.

These flanges perform several functions. First of all, by having a rolled over edge for the exposed edges, they prevent any accidental cuts or scratches from sharp edges or burrs. Secondly, they act as stiffeners, strengthening the cover and helping prevent it from bending. Finally, the wider flanges (3/4" wide) on the front cover and lid also provide a place to rivet the hinge for the lid.

After bending, check all three parts to ensure that they are evenly bent and that your bends are actually 90 degrees. If not, you can make slight adjustments to the bends by hand, without having to bother with putting the part back in the bender. Actually, once the parts are bent, you could almost flatten them by hand and then bend them again, and they would still present a clean 90 degree corner. But don't do that too many times, or you will break the aluminum sheeting.

The short tabs on the front piece and lid are for riveting the parts together. I used 3/16" diameter by 1/8" long aluminum pop rivets; but you could just as easily use 1/8" diameter ones. The main reason I used 3/16" rivets is that they fit the holes in the hinge better.

Rivets work by clamping the parts together. Since we are using soft aluminum sheeting, the rivet alone may not do all that good a job of clamping. Therefore, to improve the clamping ability of the rivet, I would recommend using backing washers. You can either buy the special backing washers made for this purpose, or you can use standard flat washers. A #10 flat washer works well for 3/16″ pop rivets and a #5 flat washer (which is a little hard to find) works well for 1/8″ pop rivets. Although technically a little large, you can substitute #6 flat washers for the #5 washers instead.

I need to mention here that the reason why special backing washers are sold for use with pop rivets is that when you put dissimilar metals together (aluminum sheet and steel washers) you increase the galvanic action, which results in more corrosion. However, unless you live somewhere that will cause the unit to be exposed to a lot of humid salt air, this shouldn't really be much of an issue. I hope you're not going to store your Backpack Electricity unit out in the rain.

In order to drill the holes for these rivets, you're going to need to back the aluminum pieces up with a scrap block of wood. I usually just clamp a piece of scrap in my vice, which gives me a stable support to drill into. Run the drill through the hole a couple of times, to ensure that it is clear. Otherwise, any burrs may make it difficult to install the rivets.

In total, you've got to rivet two flanges on the front cover and four on the lid. The locations for these rivets are marked on the bending diagrams with a red X. Each pair of Xs are close to each other and will be obvious once you bend the parts. Some acrylic adhesive may be used in conjunction with the rivets, but it is not necessary. These are approximate locations, as the locations are not all that critical.

In order to mount the EMP shielding on the Backpack Electricity unit, you'll first need to disconnect it from the battery and remove it from the backpack frame. Be sure to mark your spacers, if you haven't already, so that you can ensure that you get them back in the right places.

The back piece will need clearance holes drilled through it for the backing board mounting screws. Rather than just drill these holes the size of the screws, I recommend drilling them oversize. You don't need the holes to help locate the back piece and by making them larger, you won't run into a problem if one is slightly off.

Mark the locations for the holes in the back piece of the EMP shield by placing it over the backing board and using a center punch to mark the holes through the screw holes in the backing board.

Drilling holes through aluminum or steel sheet can be extremely difficult and the thinner the metal, the worse it is. When the drill bit punches through to the other side, it tends to grab the sheet metal and pull it, bending it. This can lead to strange shaped holes and damaged parts.

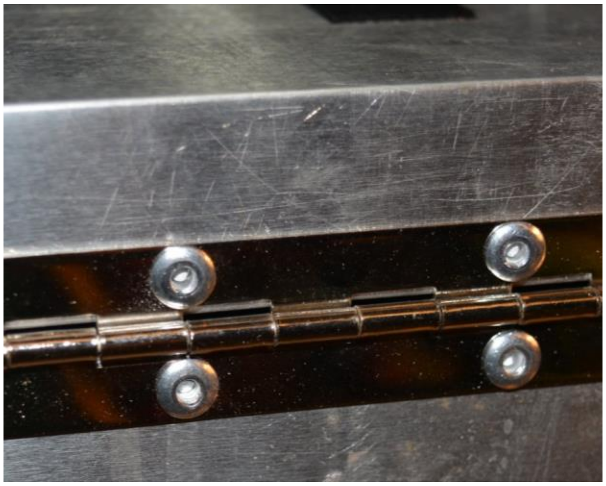
The solution for this problem is to use a Unibit or stepped drill bit to drill holes through sheet metal. The Unibit has a single cutting edge, with the body of the bit acting as a pilot to keep it properly aligned in the hole. Together with the stepped drilling action, where the hole is being widened out bit by bit, this eliminates the problems normally associated with drilling through metal sheeting.

You will need to deburr the holes, after drilling them. If you don't have a deburring tool or a large countersink, the easiest way to do this is with the Unibit itself. Simply allow the next cutting stage to make a couple of revolutions around the hole from the front side, before withdrawing the bit. Then turn over the panel and clear out the burr on that side the same way (it will be much bigger).

With the clearance holes drilled, the back piece of the EMP shielding can be placed over the back of the control panel backing board and the control panel can be reinstalled to the pack frame, using the original hardware. If the screws are a bit loose when installing them in the wood frame, put wood matchsticks into the holes, break them off and then put the screws in. It will tighten the holes right up.

The hinge for the lid needs to be installed, connecting it to the front cover, before installing the front cover to the control panel. It would be nearly impossible to do so afterwards, as there will be no way of putting a block of wood in place to act as a backing board for drilling the aluminum skin of the EMP shield.

I have chosen to use a piano hinge for the lid, otherwise known as continuous hinge. This is available in a variety of lengths at your local home improvement center. Since the control panel is 13" wide, a 12" hinge is ideal. If you can't find one the right size, it's really not a problem, as an oversize hinge can be cut down easily with a hacksaw.



As with the corner tabs that were riveted, the hinge is riveted in place. This is part of why I chose 3/16" rivets, rather than the smaller 1/8" rivets, as the 3/16" ones fit the holes in the hinge better. As with the tabs, it's a good idea to use backing washers, since our aluminum skin is so thin.

It is best to install the hinge on the outside of the EMP shield, even though it would be better protected from the weather on the inside. But if you install it on the inside, the lid will not be able to open 180 degrees, only 90 degrees. The extra space makes the unit much easier to work with.

Before installing the front cover to the unit, be sure to reattach the wires to the battery. You may not have enough clearance under the cover to get your fingers in there and connect it, once the front cover is in place. Be sure to strap the battery down good as well, so that it can't move while you're carrying it.

To install the front cover to the Backpack Electricity unit, simply slide the sides under the flanges on the back piece, being sure to push it down as far as it will go. Then, drill pilot holes through the flange and front cover and install screws through them into the backing board to hold the front cover in place. Truss head screws are excellent for this, if you can find them, as the wide head spreads the load out and improves the clamping force.

The last detail is to install some sort of latch. This isn't actually necessary, as the lid should stay closed without it. But just to be sure, you might want to add one. I've chosen simplicity, by making a simple strap out of Velcro and attaching it to the back of the EMP shield with screws into the backing board.

The lid has the mating piece of Velcro attached to it, allowing the strap to hold the lid closed.

WATCH OUT FOR THAT RAIN

Since the Backpack Electricity unit is electronic, it's a good idea to protect it from the rain. In the upgrade section of this book, I'm going to be talking about EMP shielding, which would offer some rain protection. But the EMP shield isn't really designed to be water resistant, so any help it offers, is secondary to its main purpose.

As a portable unit, chances are that your Backpack Electricity unit will be exposed to rainfall sometime, whether on a camping trip or a bug out. So, it's only prudent to make sure that it's ready for that day. That means developing some sort of water resistant cover for it.

The absolute easiest way to protect your Backpack Electricity unit from the rain would be to wear a rain poncho that's designed to cover a backpack as well. However, not everyone has such a rain poncho and besides, you may not want to wear a poncho, preferring to enjoy cooling off in the rain. But since your Backpack Electricity unit won't enjoy that, it's prudent to provide it with some sort of protection.

That's why I've gone ahead and made a rain cover for my unit. I suppose I could have just used a plastic bag, but plastic bags get torn on protruding tree limbs and other things way to easily. I wanted something that not only would protect my unit from the rain, but be sturdy enough to ensure that it would last a number of years. Therefore, I made a cover out of water-resistant fabric.

Few fabrics are actually waterproof. The main reason for this is that waterproof fabrics hold in moisture, to the same degree that they hold out moisture. If you've ever been in the Army, and worn an Army issue rain poncho, you know what I mean. Twenty minutes after putting it on, you're as wet from your own perspiration, as if you had been standing in the rain all that time, without a poncho on. Considering that, I'm not really sure why the Army bothers issuing them, except that they can be used to make a lean-to shelter in a pinch.

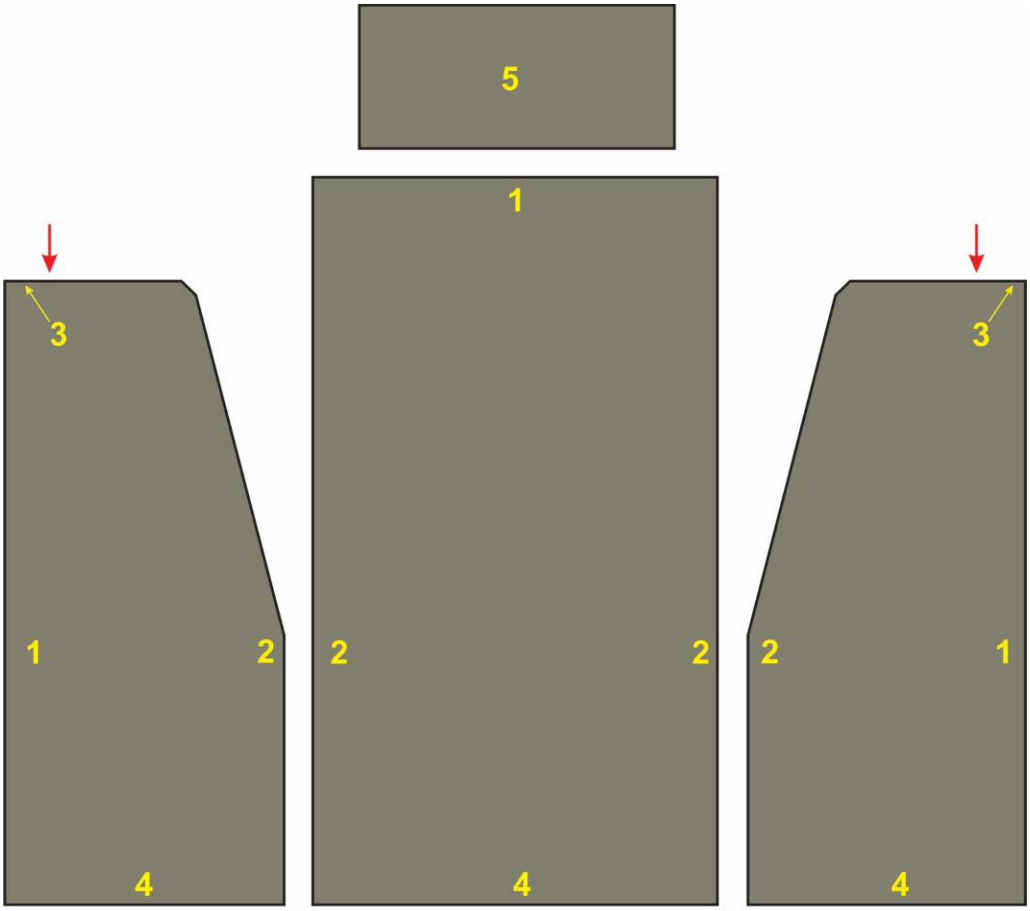
Raincoats and other wet weather gear are usually water-resistant, rather than waterproof. This means that they shed extremely well, rather than allowing the water to soak in. At the same time, these fabrics "breathe" allowing water vapor to pass through them. So, the perspiration evaporating from your body passes through the fabric, rather than condensation on the inside of it, yet the rain falling on the fabric runs off. Between the two, you are kept dry.

The two principal water resistant fabrics are Rip Stop Nylon and Arctica. Rip Stop Nylon has been used by the military for decades, for everything from uniforms to parachutes. In the civilian market, it is often used for better quality wind breakers, lightweight tents and other outdoor sportswear. It should not be confused with lower quality nylon fabrics, which are also somewhat water repellant, but not as much so as Rip Stop. Nor are they as strong. Arctica is the most commonly used fabric for rain jackets, backpacks and other fabric products which need to be water repellent.

Pricewise, Rip Stop Nylon is considerably cheaper than Arctica. You can buy Rip Stop for $6 to $8 online, while Arctica will cost about $15. For this project, I'm using some MILSPEC Rip Stop Nylon that I have leftover from another project.

Making the Rain Cover

The rain cover consists of four pieces of this fabric, sewn together to form a roughly rectangular box, with a triangular section cut out of it. This cutout is there to account for the difference in depth of the top of the Backpack Electricity unit and the bottom. Since the shelf on the bottom is designed to hold a small car battery, if necessary, it sticks out farther than the electronics mounted to the panel above. Therefore, it needs more space.



The pieces are shaped as in the diagram above. The top rectangular piece is a removable flap, intended to go over the back of the control panel, thereby closing off a potential crack along the top of the panel, where water could get in. It is attached to the main part of the unit with Velcro. I've made it separate for two reasons:

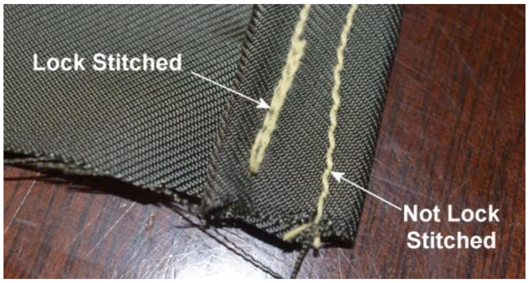
- To make it possible to open the cover up and access the unit inside, while it is still mounted to someone's back.
- To avoid weakness in the cover, caused by trying to make a seam on an inside corner. I could have just sewn the piece on to accomplish this, but then it wouldn't be possible to open it.

I've provided full dimensional drawings in the Appendix for these pieces, so that you can lay them out on your fabric and cut them. I just drew the pattern directly on the fabric, rather than bothering with a separate pattern. The pieces are simple enough that this is quite practical. Please note that the right and left pieces are mirror images of each other, so they can be cut out at the same time, by the simple expediency of folding the fabric in half.

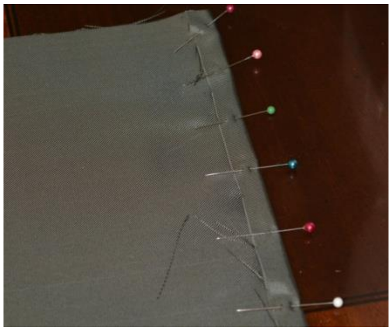
There is one little detail that I need to mention, before getting into the specifics of sewing this cover together. I'm working under the assumption that you, my reader, are a man, and are not accustomed to sewing on a sewing machine a lot. If you are familiar with sewing, you're probably going to find these instructions overly simplistic. But I felt a need to keep it simple for those who are new to sewing and sewing machines.

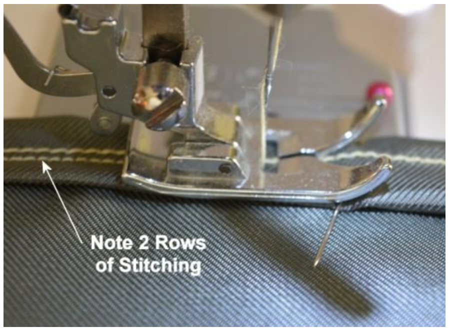
All sewing machines have a reverse function on them. This allows what is known as lock stitching. Normal sewing from a sewing machine can unravel over time. By reversing the direction of the machine and sewing back over the stitching that was just done, the stitches are "locked" in place. You'll want to do this at the beginning and end of every seam you stitch.

The numbers in the diagram above are the sewing order of the pieces. The three edges labeled with the number "1" are to be folded over twice and hemmed. This is the same sort of hem you would find in the bottom of a shirt. On the pattern, you'll see that I've given you 1/2" of fabric for the first fold and 5/8" of fabric for the second fold.



To make this sort of hem, first pin the fabric for the first fold as shown in the picture on the lower left. In order to align this correctly, I'm using a line I drew on the fabric. The fabric is folded so that the line is exactly on the outside of the fold. Once it is pinned, the hem can be sewn the first time on the sewing machine, as shown in the center photo. As you are sewing, you'll need to remove each pin as you get to it. Then, fold the fabric over and pin it again, for the second fold of the hem. This is then sewn, a little to the side of the previous sewing, as shown in the picture on the right.





As you can see, I'm not the best seamstress in the world. That's why my lines aren't exactly straight. However, I am sure that they will hold and that's what's necessary. The yellow thread I am using is actually aramid fiber, the same thing that is used to weave Kevlar. It is extremely strong, which makes it ideal for projects of this sort, where you don't want to have to worry about the thread breaking and it falling apart.

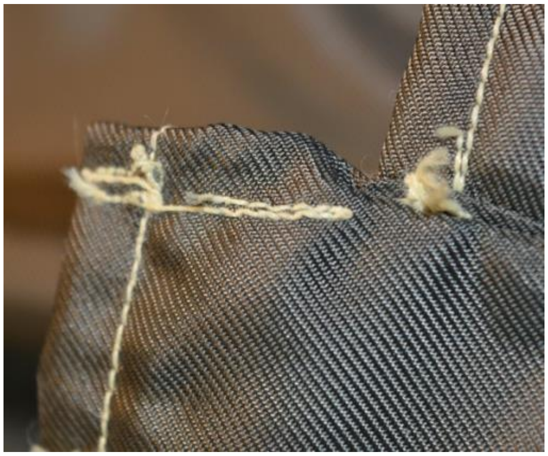
There is a flip side to that coin though. Aramid is so strong that you can't break it; you have to cut it. That also means that if you make a mistake, it's extremely hard to take the stitching out and redo it. You're better off just leaving it in, unless you absolutely have to remove it because the parts are positioned incorrectly or some such problem.

You don't have to use aramid thread like I am. Regular sewing thread will work just fine. I am using it because I have it available. A secondary advantage in this case, is that it allows you to see how I have sewn the parts together, even though it isn't as neat as my wife could do it.

Sewing the seams numbered "2" in the diagram is done with the cover inside-out. The top edge of the center panel (which is already hemmed) is attached one inch from the top hemmed corners of the side panels, as indicated by the red arrows in the diagram. The reason for this is to allow for the thickness of the wood backpack frame. The extra inch of material on the side pieces will be attached to the sides of the frame with Velcro.

Working with one side at a time, pin them to the center piece, and sew them. I found it easier to pin and sew the short seam across the tops of the side pieces and then pin the longer run down the front of the cover. I triple stitched these seams, with my first seam being about 3/8" from the edge of the fabric and my second seam being about 1/2" from the edge. I then used a zig-zag stitch on the sewing machine, closer to the edge of the fabric. This is there to help prevent fraying of the edge.

With the center panel starting one inch from the corner of the side panels, you'll find a small flap of unhemmed fabric left over at the end, where the number "3" is on the diagram. This is that last one inch that you didn't attach the center panel to. Fold this flap over to the back and stitch it in place, just as you did with the first fold when hemming the sides labeled "1."



When the three panels are sewn together, the bottom edges of all three should be in alignment (the edges marked "4"). If they are not, a little adjustment with a pair of scissors would be in order. Your next step is going to be treating this edge as if it were one piece of fabric, so you'll want it to be straight.

We're going to put a piece of elastic on this bottom edge, in order to force it to close around the bottom of the backpack frame shelf. So, what we need to do is to create a casing for the elastic to go into. This is similar to hemming the fabric, with the exception that the second fold is larger to leave enough room for the elastic to go through. You'll notice on the pattern drawings that I left 3/4" for the second fold along this edge. That space is to create the casing.

Go ahead and sew the casing, just like you did the hem at the locations marked "1," with the first fold being 1/2" and the second fold being 3/4". Please note that when sewing this second fold, you'll need to sew near the edge of the fabric (1/8" to 3/16"), so as to leave as large an opening as possible for the elastic to go through.

Once the casing is done, you can run the elastic through it. I used 1/2" elastic. To get it through the casing, attach a safety pin to the end of the elastic. That will give you something you can feel through the fabric, so that you can work it through the casing.

Sew one end of the elastic by hand at one end of the casing, doing several overlapping stitches to lock them in place. Then stretch the elastic about 50% and sew it at the other end as well. Please note that you don't want to stretch the elastic to the point where the fabric can't lay flat when the elastic is stretched, even though it will be bunched when you let go of it.

Cut another piece of elastic 8" long and sew it by hand from near one end of the casing to near the other end, where the blue arrows are in the diagram. This will act as a strap across the bottom of the shelf, so that the elastic can pull together around the bottom of the shelf. Without this the ends would hang out, rubbing against the wheels.

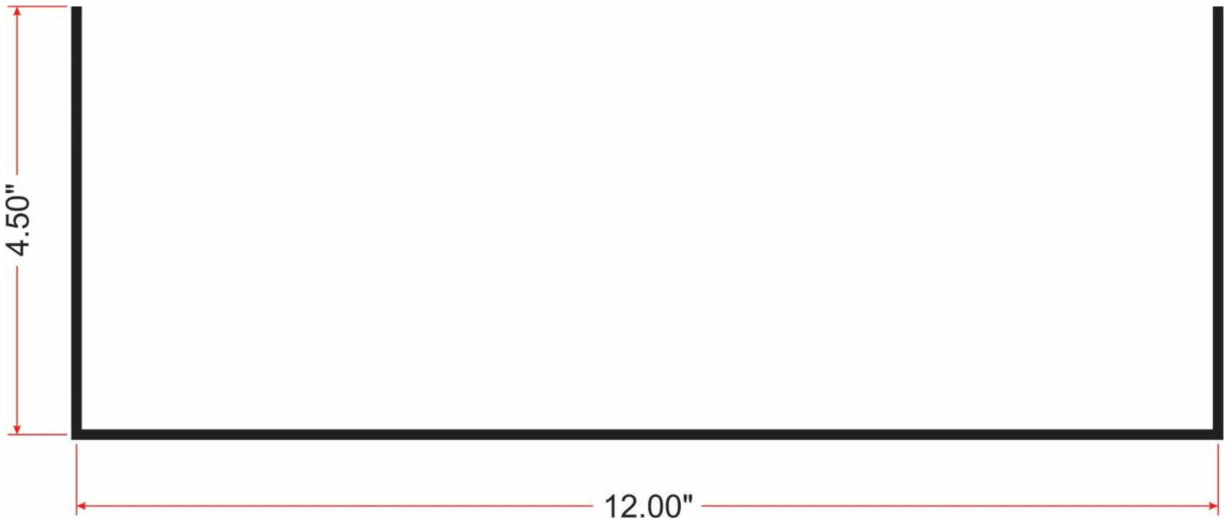
Supporting the Cover

I have decided to add a support to the Backpack Electricity unit for the rain cover. This is not actually necessary, as the cover will attach to the frame just fine without it. But I'm the kind of guy who likes things to be nice and neat, so I decided to add it. Besides, it didn't take very long to make.

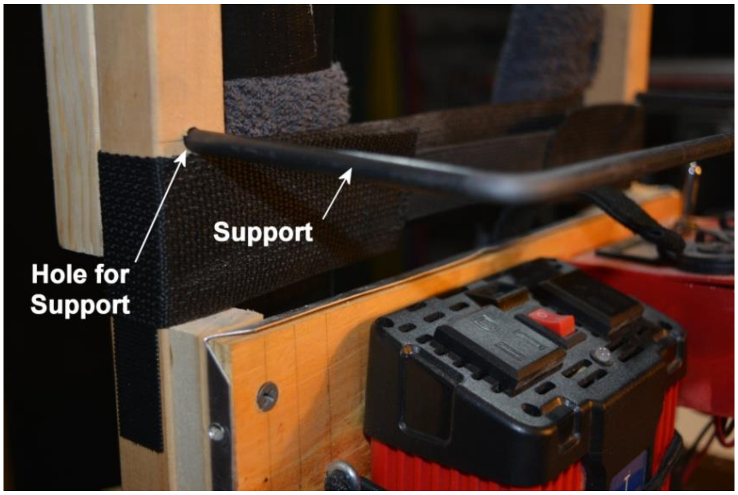
My support is made out of 1/4" diameter steel rod. If you can't find that, you could probably make it out of smaller diameter rod, such as brazing rod. I've used materials like that for a number of similar projects with great results.

The support itself is nothing more than a squared off C, as shown by the drawing below. I made this by cutting a 21" piece of the steel rod and bending it in my vice. I had to use a hammer to make the bends, so that they would come out as a 90 degree angle and not a sloppy curve. Once bent, I checked them with a square.

My bends were slightly off plane with each other, leaving one of the ears up and the other down a bit. However, with this type of material, this is easy to correct. All that I had to do is clamp one ear in the vice and twist the other slightly to align them. It took a couple of tries to get it perfect, but in the end it worked out just fine.



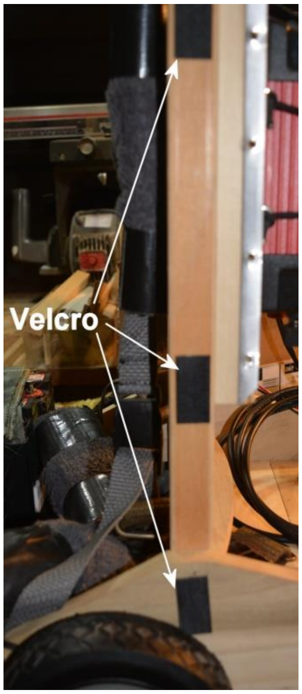
To attach the support, I drilled two holes in the vertical members of the wood backpack frame. They are 2-1/4" above my control panel, leaving space for the comfort strap, centered on the vertical members. In order to avoid drilling the holes too deep, I wrapped masking tape around the drill bit, 5/8" back from the end.



[Support shown without EMP shield in place.]

Although this is 1/4" rod, that's a nominal dimension. My rod was actually a touch over that. So, I ended up having to drill the holes out to 17/64", while maintaining the same depth, in order to hold the ends of the support.

The only thing that is holding the support in place is friction, so you want the holes in the frame to be snug, so as to prevent the support from falling out. So make sure you measure carefully the diameter of the steel rod used to make the support. The 5/8" hole depth is deep enough to hold the support in place, if the hole is snug.



Attaching the Cover

The easiest way to attach the cover to the backpack frame is with Velcro. Most Velcro you buy today is "self-stick," meaning that it has an adhesive on the back side. While it is true that the product will stick to most surfaces, it's not true that it will stay where you put it. The cohesive force of the Velcro itself is usually higher than the adhesives they use. So, when you try to pull the

Velcro apart, it often comes off the surface you've stuck it too.

The only real solution to this is to attach the Velcro mechanically to the substrate. For fabric, that means sewing it in place. The adhesive works well to hold the Velcro in place while you are sewing it, but you'll want to sew it in place as well. On substrates like wood, the adhesive works fairly well; but if you want to make it secure, you should staple it as well.

I've put eight pieces of Velcro on the frame. Three go on each side, one at the top of the rain cover, one at the bottom of it, and the third in the middle. The last two go on the back side of the control panel, so that the corners of the rain cover flap can be held in place.

Between these pieces of Velcro, the elastic band at the bottom and the support, the rain cover is held in place securely. It can be opened either by separating the Velcro at the top flap, giving access to the connection panel, or by removing the Velcro and taking it off entirely.

Using Your Backpack Electricity Unit

Now that you've gone through all that trouble of building your Backpack Electricity unit, it's time to use it. I've got good news for you here; using it is simplicity itself. While building it took some time and effort, once built, the finished Backpack Electricity unit all but runs itself.

There are basically two parts of using the unit, both of which can be done simultaneously. They are:

- Charging the battery
- Powering your electronics

Charging the battery will happen any time you set the solar panels up and connect them to the unit. You should do this as often as you can, especially if you are actually using your unit to power electronic devices. But even if you aren't, all rechargeable batteries lose some charge while sitting on the shelf. So, even if you are just keeping it in reserve, it's a good idea to set up the panels and charge it every couple of months, just to keep the battery topped off.

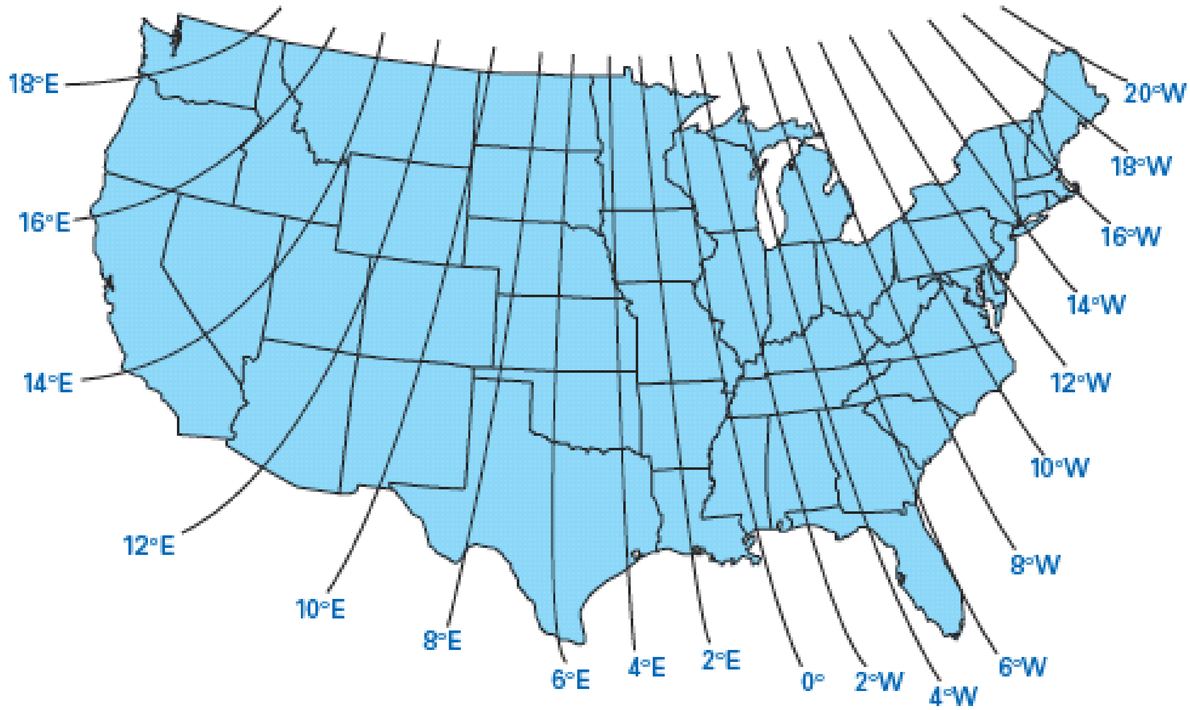
Using the unit to power your electronics is even easier than that. All you need to do is to connect the electronic device to the appropriate jack on the voltage inverter or control panel. You'll have clean, abundant electrical power, for as long as the battery's charge lasts. If you connect the solar panels at the same time, you'll be able to extend that time.

Now, here's the one thing that's a touch tricky. That's setting up your solar panels for the maximum efficiency. Ideally, you want the sun's rays to come perpendicular to the solar panels' face, so that the solar cells are hit full on. That's rather hard to do, without some rather sophisticated equipment; most specifically, a sun tracker.

But even without a sun tracker, you should still try to optimize the efficiency of your solar panels. That means pointing them directly south and at the right angle. So, let's look at what you need for that, in a little bit of detail.

To start with, here in the northern hemisphere, the sun is always south of us. So, that means we want the solar panels to point south. You could take a compass and use it to find south, and then just point the panels in that direction. But magnetic south and true south aren't exactly the same thing. They are slightly different. This difference is called the "magnetic declination."

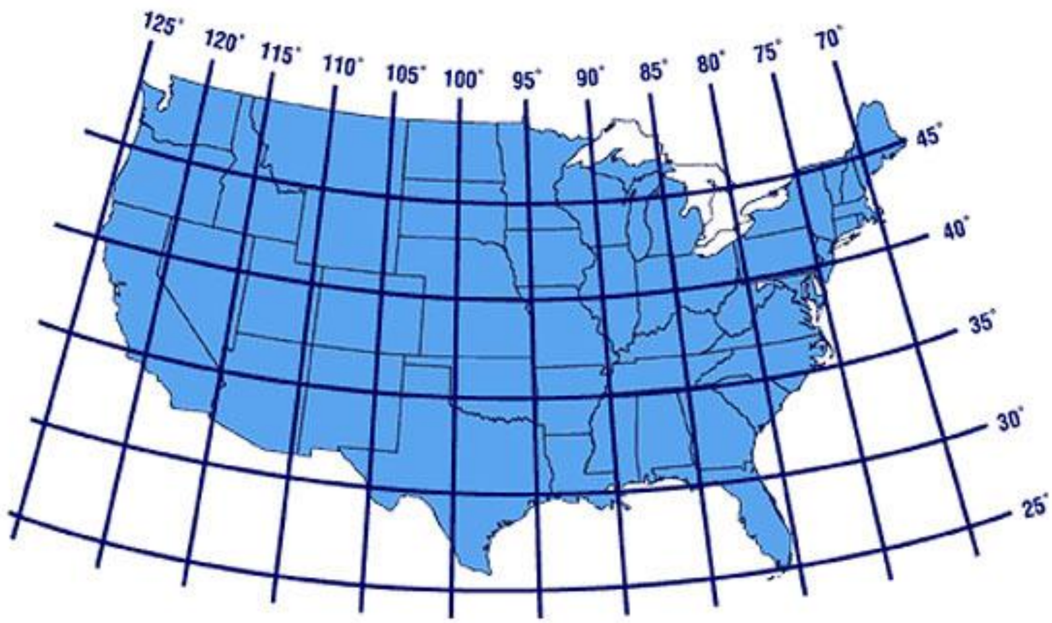
Magnetic declination changes, depending on where you are. The map below of the United States shows what the magnetic declination is across the country. By adjusting the direction your compass shows you by the amount shown on the map, your solar panels will be pointed more correctly towards true south and their efficiency will increase slightly.



But that just takes care of the direction your solar panels should be pointed in; it doesn't do anything for the angle that the panels are set to. By angle, I mean how vertical or horizontal they are. As you know, the sun's path through the sky appears to change through the year. This is caused by the wobble in the Earth's orbit and is what gives us our seasons. It also affects the angle by which the sun's rays are hitting solar panels.

If you were building a fixed solar installation, you'd set your panels to an average angle for the year and leave them there. But since this is a portable unit, you'll probably want to adjust the angle, depending on the season. This is calculated differently for each season, so you can have the best possible angle.

So, there are two key pieces of information you need, so that you can choose the best angle for your solar panels; the date and your longitude. Hopefully, you know the date and you can get the longitude for where you are from the map below.



With the longitude of your location from this map, and the date, you're ready to go. The following table gives you the formulas you need to calculate your solar panel angle.

Season	Dates	Formula
Spring	March 5 - April 17	Multiply the latitude by 0.98 and subtract 2.3 degrees
Summer	April 18 - August 23	Multiply the latitude by 0.92 and subtract 24.3 degrees

Autumn	August 24 - October 6	Multiply the latitude by 0.98 and subtract 2.3 degrees
Winter	October 7 - March 4	Multiply the latitude by 0.89 and add 24 degrees

This gives us the following set of results:

Latitude	Spring Angle	Summer Angle	Autumn Angle	Winter Angle
25°	22.2	-1.3	22.3	46.3
30°	27.1	3.3	27.1	50.7
35°	32.0	7.9	32.0	55.2
40°	36.9	12.5	36.9	59.6
45°	41.8	17.1	41.8	64.1
50°	46.7	21.7	46.7	68.5

Please note that this angle is off of zero. For our purposes, zero is the panel sitting perfectly horizontal, pointing straight up at the sky. So, if you live at 30° latitude, you'll want to have the panel pointing almost straight up, in the summertime, but not quite. It should have a 3.3 degree angle towards the south, for the best efficiency.

The one truly confusion number on that chart is for people who live at a 25° longitude, at the very southern tip of Florida. It shows that the tilt angle should be -1.3 degrees in the summer. That means that the panel should actually be pointing 1.3 degrees towards the north, not the south, for those three months. But then, that's only a very small percentage of our total population.

If you are traveling, camping or bugging out, you can set this angle by leaning the solar panels against convenient rocks, trees or anything else that won't move. But for a home installation, you'd want to make some sort of brackets, which will allow you to adjust the angle, but would hold it in place, once adjusted. Typically, in such an installation, people mount multiple panels together in a bracket, or install them on tracks, mounted to the roofs of their homes.

You're On Your Way

The information that I've given you in this book and its accompanying videos will allow you to build your own portable solar power generator. Used properly, this will ensure that you are never without electrical power again. You and your family will be more secure and more self-sufficient than ever before.

But that's not saying that you should stop here. Your family regularly uses much more electrical power than this unit, as we've built it, can provide. However, this can serve as the nucleus for an ever-expanding home power generating system. There's no reason why you need to stop here; you can continue until you are producing all your own clean, free electrical power.

By building your own solar panels and system, you save about half of what commercial panels would cost you, as well as the cost of having a contractor designing and installing the system. That difference could very well mean the difference between making solar power affordable to you and keeping it out of your reach. I know that I can't afford to have a contractor design and install solar power for me, but at the costs we've incurred in this project, I've found that I can afford to build my own solar panels.

One nice thing about this is that I can build my system a little at a time. The Backpack Electricity system, with its four solar panels, isn't going to provide anywhere near the amount of electrical power my family uses on a daily basis. But it's a start. Even if it only saves me a few percentage points on my electric bill, that's more money I have for other things.

Better than that, it's money that I can save for buying the parts to build more solar panels. While it may be a while before I have enough to make a significant difference in my monthly energy costs, it's permanent savings. In other words, whatever I save, I save every month from then on.

With rising energy costs and Obama's war on coal, being able to save money on my energy bills is a priority in my life. I don't know about you, but I can't afford to see my monthly energy bills rise by 50% over the next few years. The rise over the last five years has been bad enough. I live in a hot climate, and my wife's body can't stand the heat. So, I need to use air conditioning most of the year. I can't cut that out to save on my electric bills. But if I can produce my own electricity, I can keep my family comfortable, without having to pay those high bills.

At the same time, I still have my Backpack Electricity unit, which I can use on a camping trip or a bug out; anywhere I need power. So, I'm gaining double duty from that part of the system. As a long-time survivalist, that's actually the greater gain to me. I know that regardless of what happens, I and my family will be better off, because we'll at least have some electricity.

Tell me, what is that peace of mind worth? To me, it's well worth the time and effort to make this system. I'll gladly invest a little bit of money and a few hours of time, to provide my family with an added layer of security, especially considering the increasing frequency of power outages in our country. I don't want my family to suffer, even if everyone else is. They're too important to me.

Plans, Tables & Lists

PARTS LIST FOR BASIC UNIT

Used For	Part Description	Qty	Source	Cost[11]
Power generation	3"x 6" Solar cells	36	eBay seller - topsolar_china	$44.83
Stringing solar cells	Tabbing wire		Came with solar cells	~
Connecting strings	Buss wire		Came with solar cells	~
Soldering cells	Solder flux pen	1	Came with solar cells	~
Soldering cells	Solder		My workshop	Nominal
Backing board	5mm, 4'x 4' Underlayment p/n 757295000115	1	Home Depot	$8.97
Sealing backing board	Latex paint	~	My workshop	Nominal
Sealing solar panel & solar cell adhesive	Silicone caulking	1 tube	Home Depot	$5.92
Spacer & sealing of solar panel to glazing	Double-sided adhesive foam	2 roll	eBay seller - blackduckdeals	$6.99

[11] Cost is total cost for the quantity used, but does not include tax or shipping.

Glazing	"Optix" Plexiglass 32"x 44" p/n 11235	1	Lowe's	$25.98
Panel power leads	14 gauge red/black Zip cord cat # WRB-14	4'	www.AllElectronics.com	$2.40
Power plug	2-conductor weather-resistant connector, 14 gauge - cat # CON-319	1	www.AllElectronics.com	$2.40
Solar panel Frame	Aluminum C-channel 3/4" x 3/4" x 1/8" thick 6063-T52	12'	www.OnlineMetals.com	$17.22
Frame corner brackets	3" Flat corner brace p/n 030699152964	4	Home Depot	$3.27
Mounting corner brackets	#8 Machine screws	16	My workshop	Nominal
Solar charge controller	30 Amp PWM Controller p/n CMTP02	1	eBay seller - topstore222	$14.02
Battery	Mighty Max 12v 7.2 AH sealed lead-acid battery p/n ML7-12	1	eBay seller - ecomelectronics	$16.99

Voltage Inverter	750 Watt Voltage Inverter item # 66817[12]	1	Harbor Freight Tools	$44.99
Backing board	1/2" plywood scrap	1	My workshop	Nominal
Attaching parts to backing board	#8-32 x 1-5/8" Eye bolts p/n 887480166712	8	Home Depot	$4.72
Attaching solar charge controller	#6-32 x 1/2" pan head sheet metal screws	4	My workshop	Nominal
Used For	**Part Description**	**Qty**	**Source**	**Cost[13]**
Backpack harness	14 gauge red & black hookup wire	3'	My workshop	Nominal
Backpack harness	Various crimp connectors		My workshop	Nominal
Solar panel harness	14 ga Outdoor cable 14/2	18'	www.AllElectronics.com	$8.10
Solar panel harness	2-conductor weather-resistant connector, 14 gauge - cat # CON-319	1	www.AllElectronics.com	Cost included in panel
Solar panel harness	1/4" heat shrink tubing	8"	My workshop	Nominal

[12] A smaller voltage inverter can be used. I used this one because I had it. Harbor Freight has a 400 watt one, which is sufficient for the basic unit for $25.99

[13] Cost is total cost for the quantity used, but does not include tax or shipping.

Backpack	Day pack	1	My workshop	Varies
Panel harness	1" wide webbing	6 yd	Hobby Lobby	$8.70
Panel harness	Buckles	5	Hobby Lobby	$7.95
Total (with 1 panel):				**$223.65**

Please note that the suppliers listed are those that I used. Just about everything on this list can be purchased from a variety of sources. eBay is a great source for unusual parts, such as the solar cells. Shop around and see where you can get the best deal.

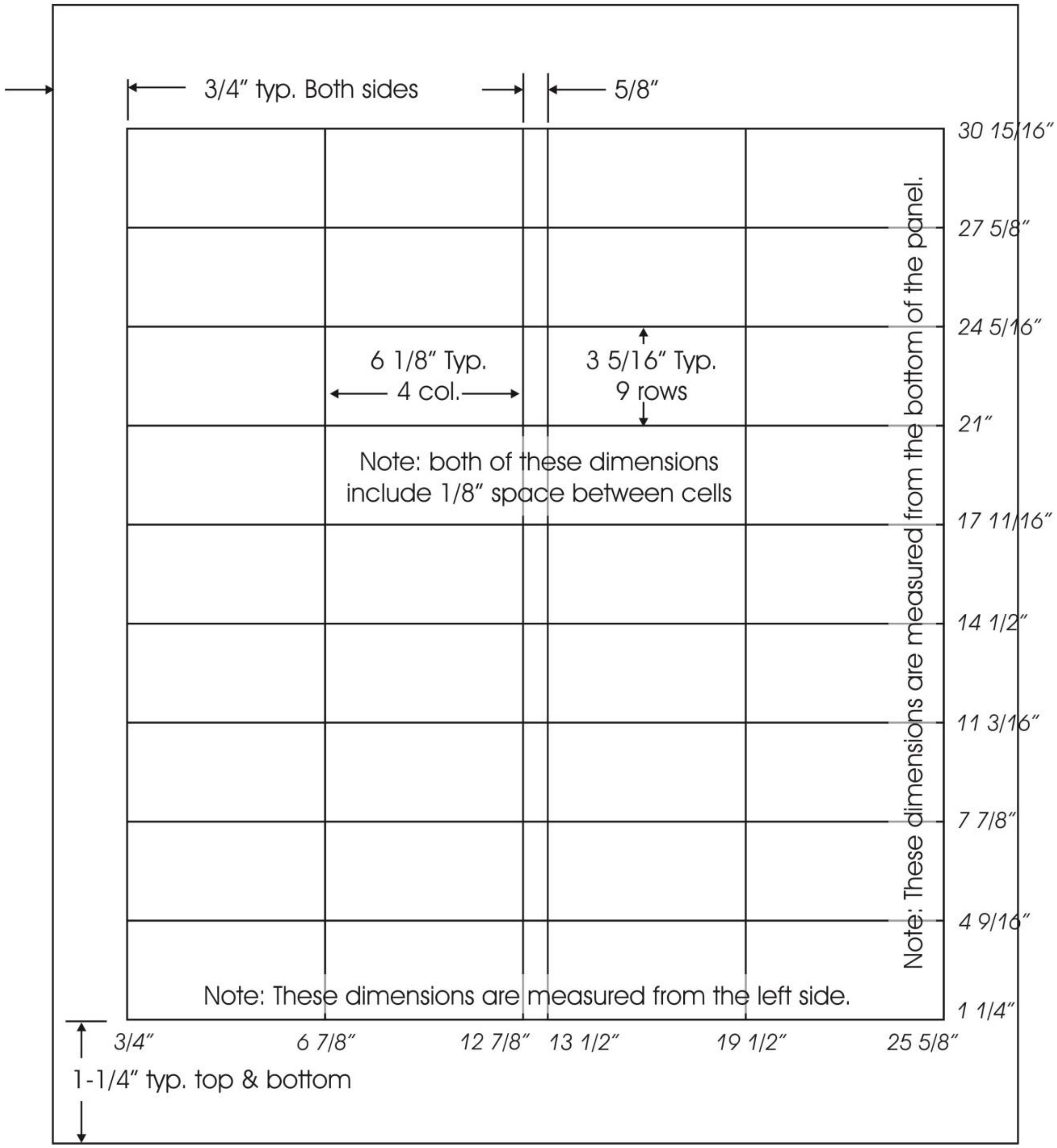
[14]Most hardware items are not listed, simply because I used what I had available in my workshop. Where specific items were purchased, I've included them in the list.

[14] The quantities listed for the solar panel are for one panel. Additional panels would mean multiplying these quantities by the number of panels you are going to build.

CELL LAYOUT FOR 36 - 3"X 6" CELLS

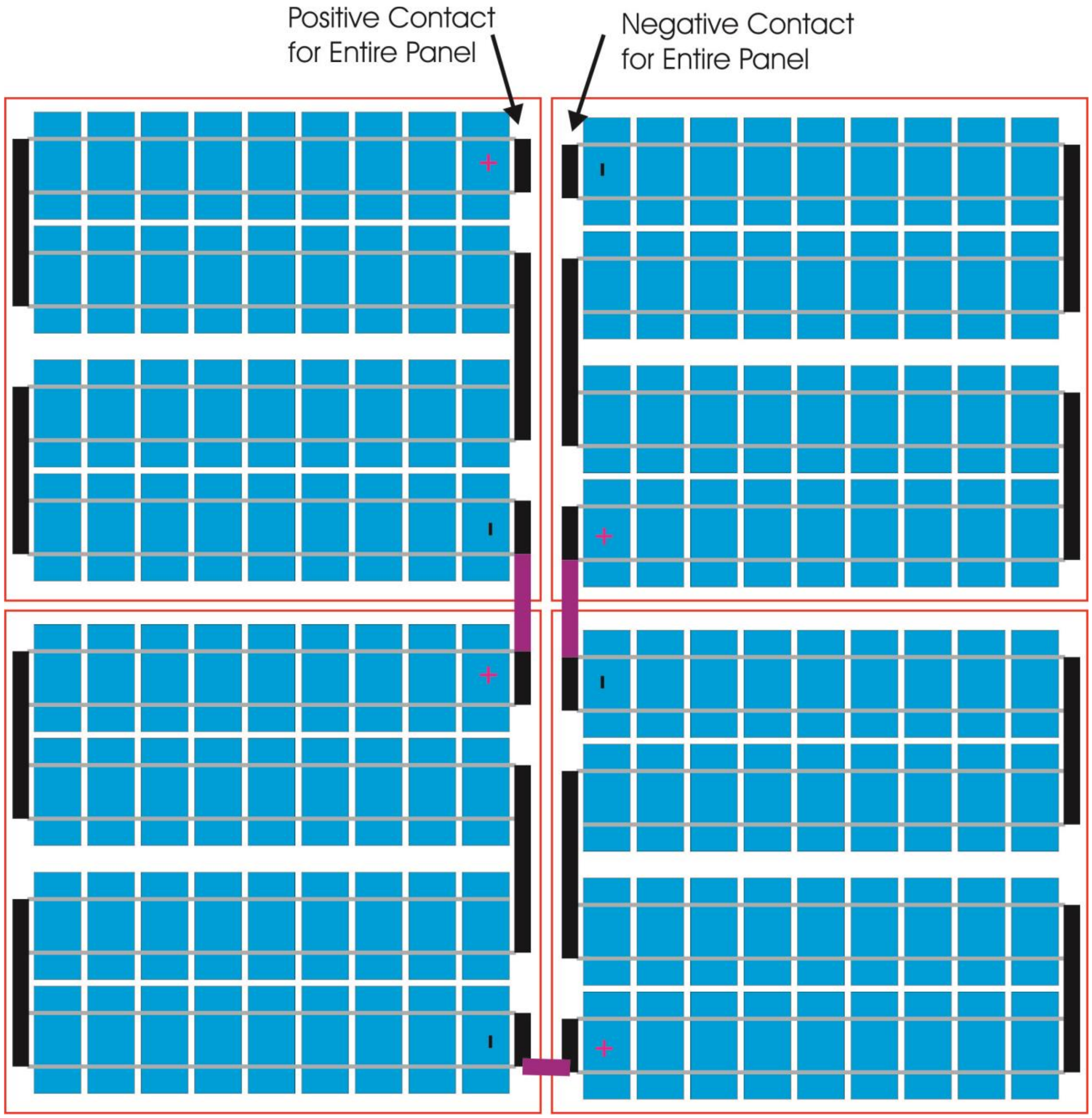
Panel Layout for 3"x 6" Cells

Overall size - 26-3/8" x 31-11/16"



LARGE SOLAR PANELS

Multiple strings can be put together to form large panels. In the diagram below. Four strings of solar cells, or four of our basic 2 cell panels, are combined together to make one large panel. Each string is outlined in red to identify them and the additional buss wires needed to connect the panels together is shown by the thick purple lines.



PARTS LIST FOR MID-LEVEL UNIT

Used For	Part Description	Qty	Source	Cost[15]
Wood pack frame	1" square hardwood dowels	2	Home Depot	$7.16
Wood pack frame	1/2" x 4" x 2' poplar	2	Home Depot	$5.16
Wood pack frame	1"x 3" x 6' poplar	1	Home Depot	$8.12
Wood pack frame	1/4" dowel pin - Item #81601	1	Lowe's	$1.98
Sub-total:				**$22.42**
Metal pack frame	22 ga. 1" square steel tubing	10'	Steel Mart	$7.50
Metal pack frame	1/8" x 1-1/2" steel strap	2'	Steel Mart	$5.00
Metal pack frame	Welding wire	~	My workshop	$0.00
Sub-total:				**$12.50**
Pack belt & straps	Alice pack belt	1	Local Army surplus store	$10.00
Pack belt & straps	2" webbing	4'	Hancock Fabric	$13.96
Pack belt & straps	1" webbing	5'	Hancock Fabric	$12.95
Pack belt & straps	Buckles	2	Hancock Fabric	$3.98
Pack belt & straps	1" elastic	1'	Hancock Fabric	$1.99

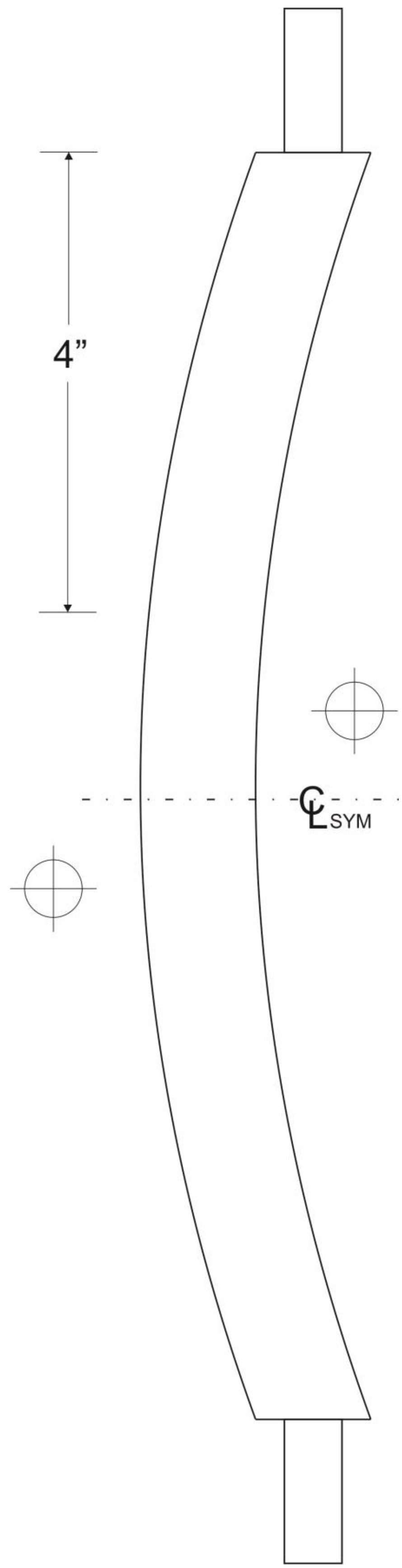
[15] Cost is total cost for the quantity used, but does not include tax or shipping.

Pack belt & straps	Washcloth	5	Dollar Store	$8.75
Pack belt & straps	Foam rubber	1' sq.	My workshop	$0.00
Pack belt & straps	Duct tape (black)	~	My workshop	$0.00
Pack belt & straps	Thread	~	My workshop	$0.00
Sub-total:				**$51.63**[16]
Battery	12v Deep cycle lead-acid battery	1	Auto Supply	Varies
Battery	NiMH Battery pack (used)	1	Local carpenter	Free
Recondition Battery	Baking Soda - large	1	Local supermarket	$2.12
Recondition Battery	Epsom Salt	1	Local supermarket	$2.86
Sub-total:				**$4.98**

[16] A large part of the reason that this price is so high is that we bought just about everything for it, mostly at the local fabric store. If you were to use straps off of an old day pack you had sitting around, a sturdy belt you had in the closet and some scrap fabric (to cover the foam pads), perhaps from an old work shirt, you could eliminate most of this cost. You could also save by buying buckles and webbing on eBay.

WOOD BACKPACK FRAME - PATTERN FOR CROSSBARS

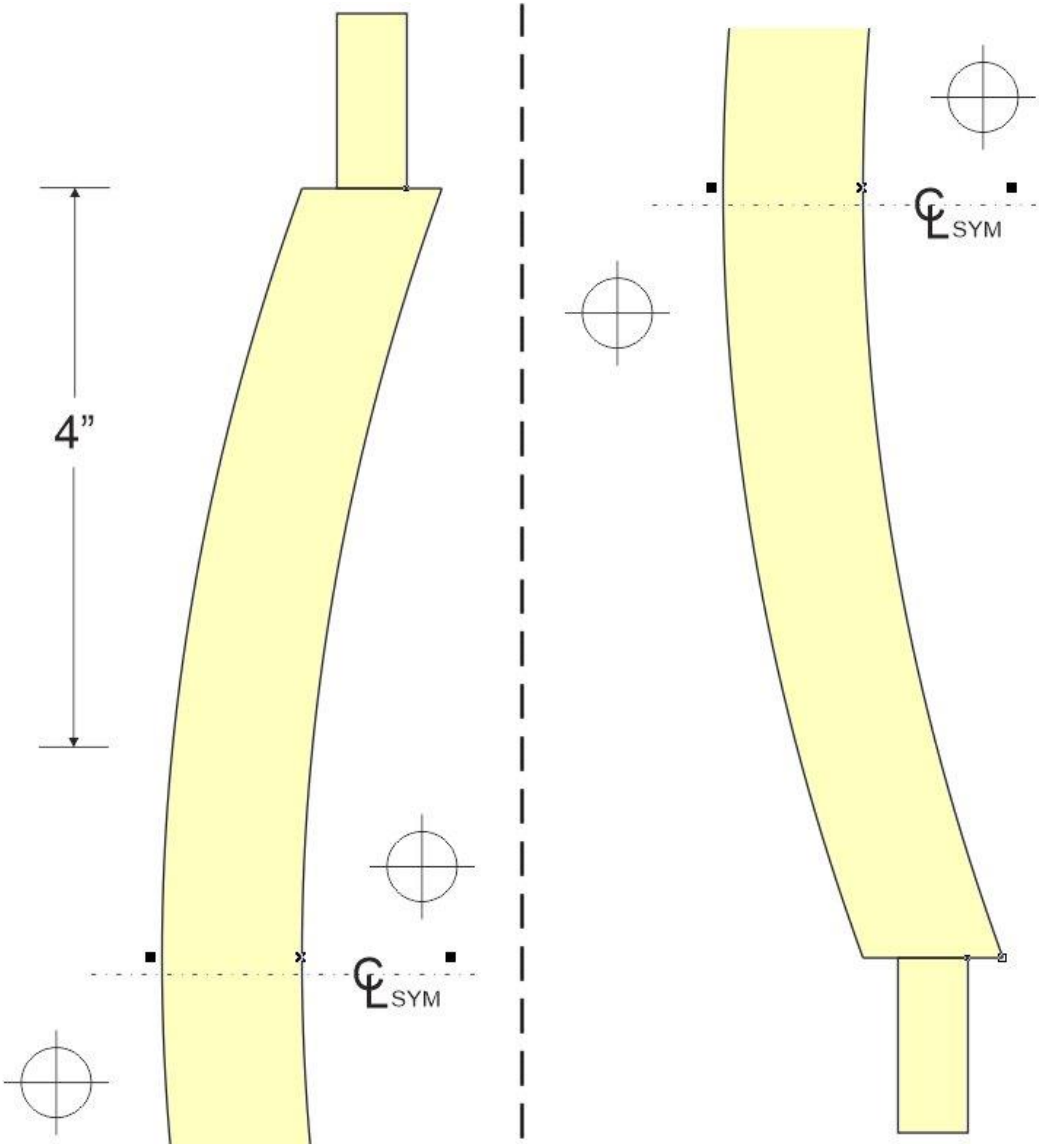
Print the next page and check the 4" dimension shown, to verify that the pattern printed the correct size. Cut out the two pieces of the pattern below, leaving the bulls-eye symbols attached. You can use those to align the two pieces of the pattern, placing one on a window and overlapping it with the other. The light coming through the window should allow you to see the bulls-eyes on the bottom piece of paper. Tape together with the bulls-eyes aligned.



The diagram to the right shows how your pattern should look, once fully assembled. Trace this onto your wood for cutting and then cut the profile of the cross brace to use as the pattern for the pieces.

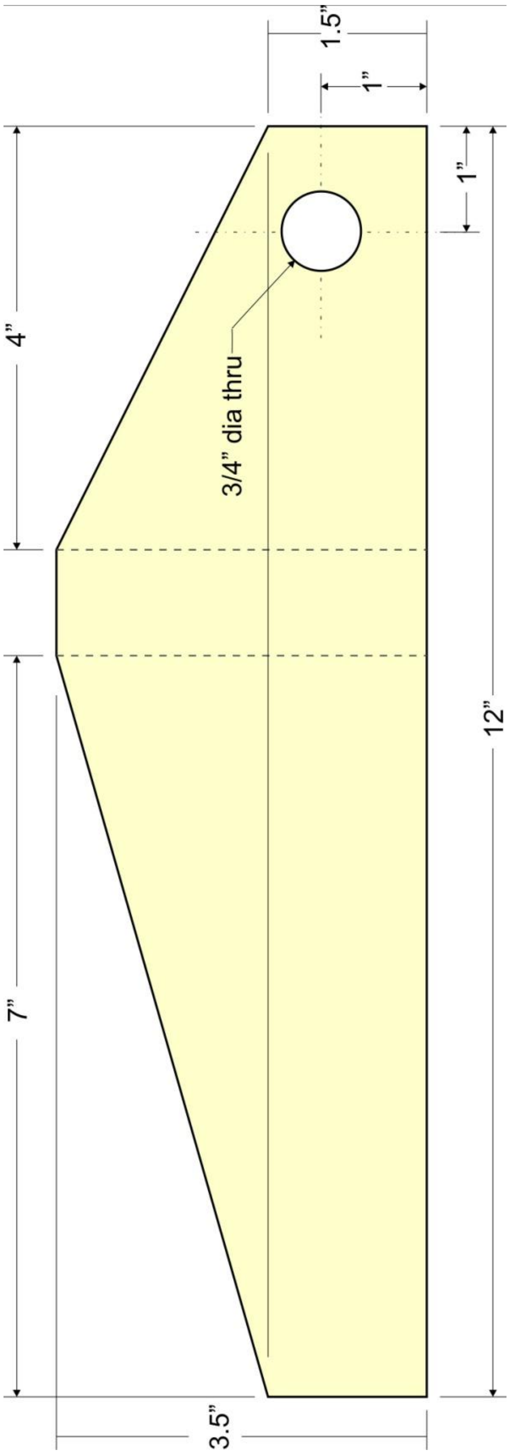
You will need two of these pieces, cut the same, as mentioned in the text. Cut them out of 3/4" thick hardwood; I mentioned poplar in the text as the wood which I chose.

The "CL" symbol on the diagram refers to that line as the centerline of the pattern. The letters "SYM" after it refer to the fact that the pattern is symmetrical across that centerline.


4"
CL SYM
CL SYM

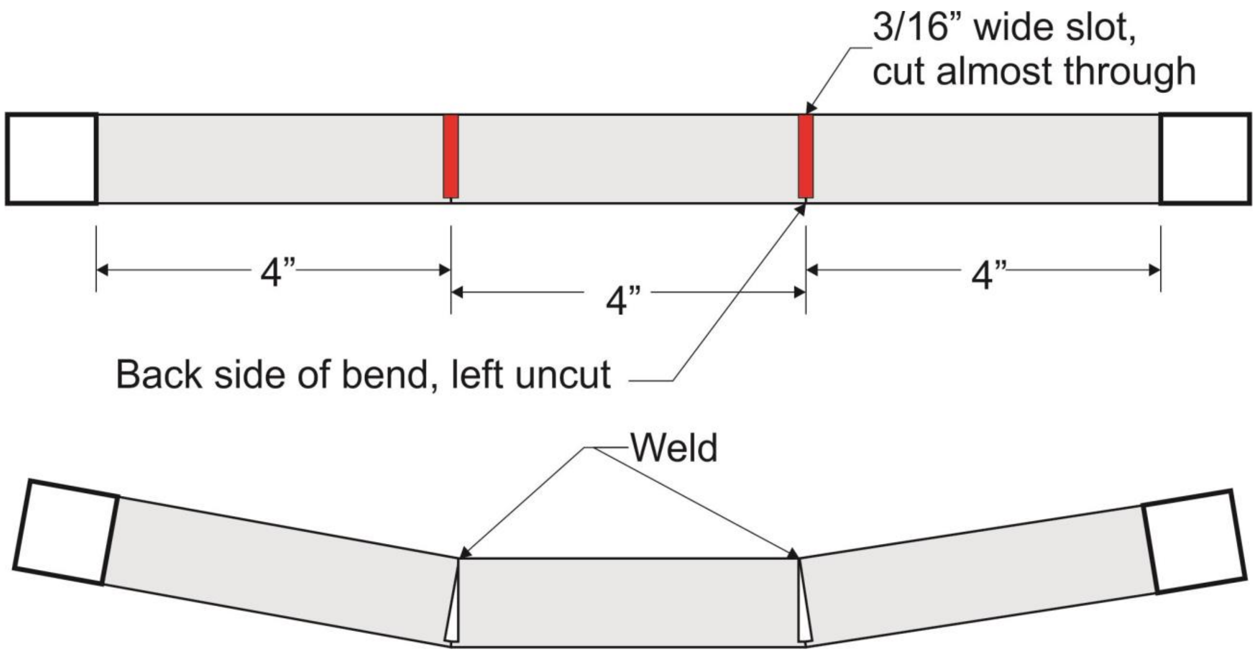
WOOD BACKPACK FRAME - SHELF BRACKET

This bracket is cut out of a 1/2" thick poplar board, 4" nominal width (3-1/2" actual width). Two are required. Draw in the two lines that are dashed on the drawing, to use as reference when attaching the brackets to the frame.

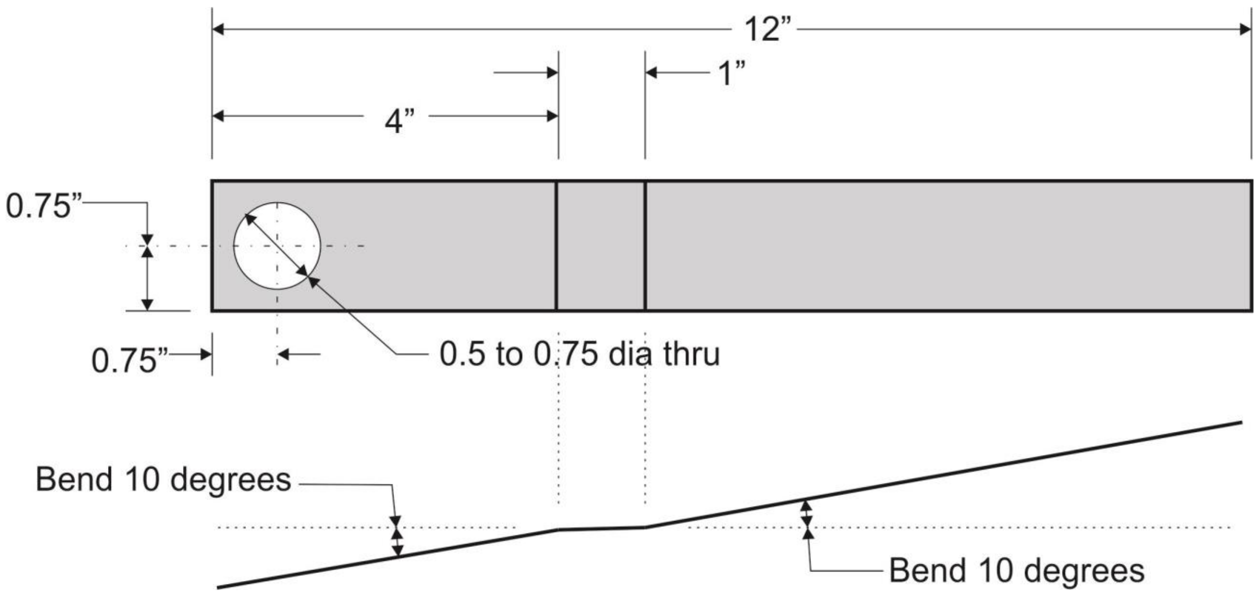


METAL BACKPACK FRAME

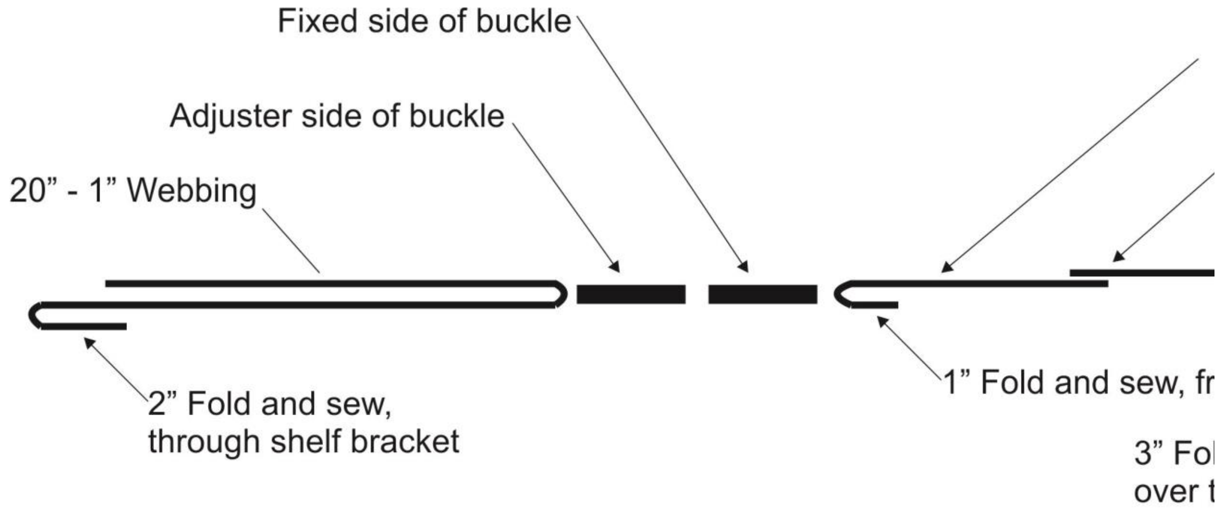
The crossbars are cut almost all the way through, for bending. The bend isn't completed until after the crossbars are welded to the vertical members.



The shelf brackets on the metal backpack frame need to be bent, to make up for the vertical members being at an angle.



SHOULDER STRAPS & BELT



PARTS LIST FOR ADVANCED UNIT

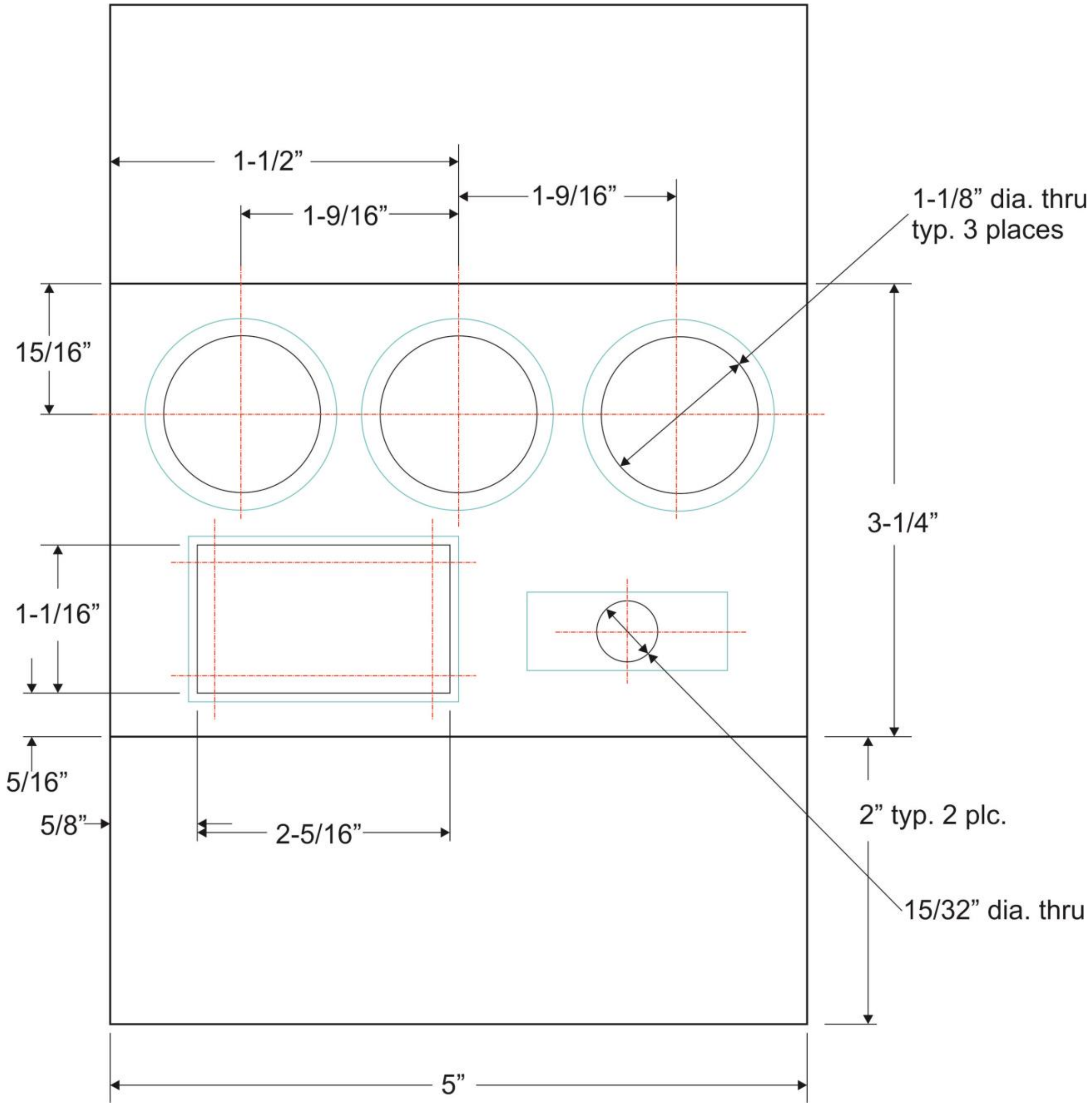
Used For	Part Description	Qty	Source	Cost[17]
Connection Panel	5″ x 8-1/4″ Plexiglas	1	Scrap from your solar panels	$0.00
Connection Panel	Automotive 12V cigarette lighter/accessory connector	2	eBay seller - sunnyshop06	$5.98
Connection Panel	Dual USB 5V automotive adapter/charger	1	eBay seller - jimshop268	$13.60
Connection Panel	Digital Volt Meter - p/n 6BX4793	1	Newark Electronics (newark.com)	$23.23
Connection Panel	Wire & crimp connectors	~	My workshop	$0.00
Connection Panel	Pop rivets	4	My workshop	$0.00
Sub-total:				**$42.81**

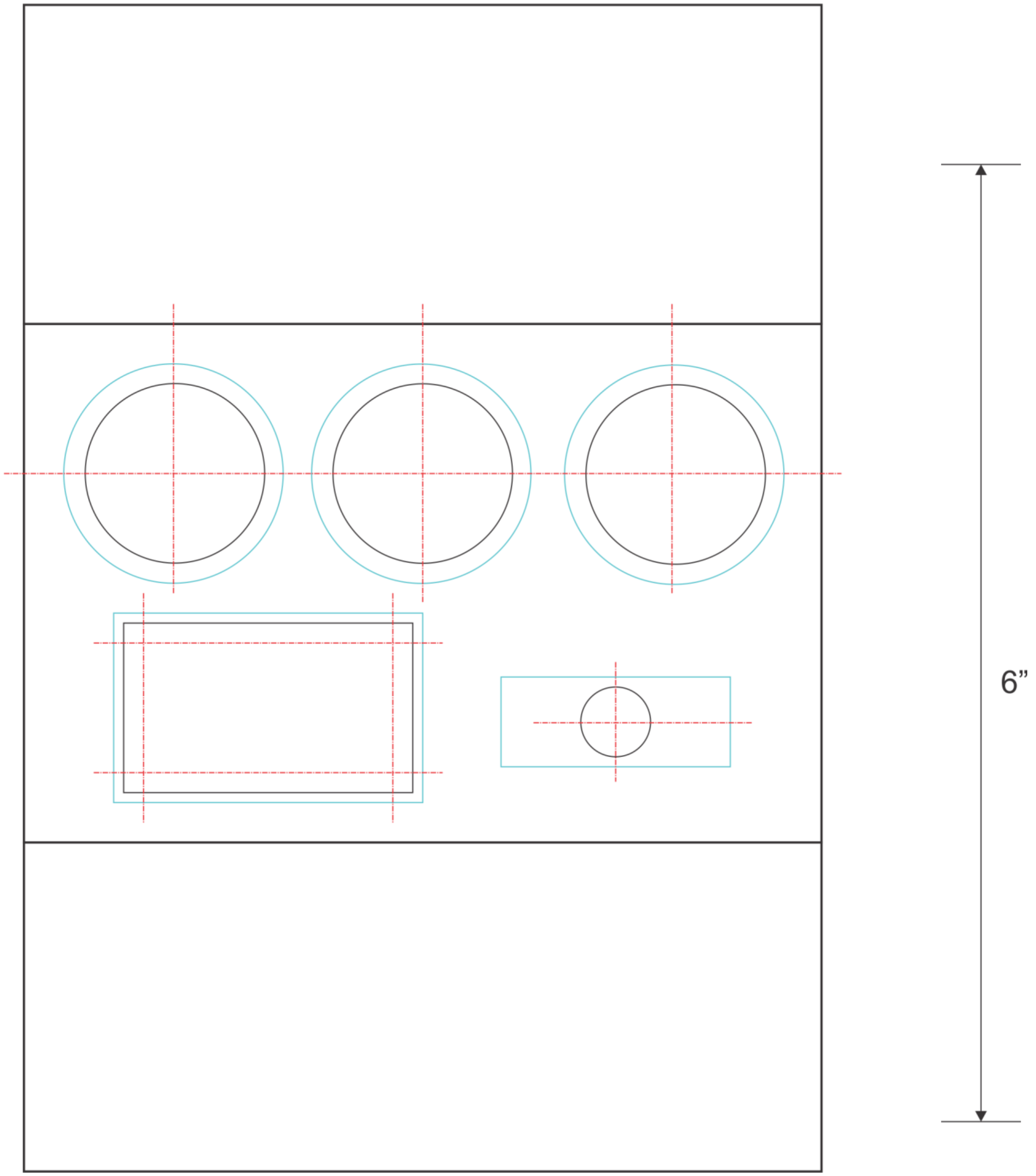
[17] Cost is total cost for the quantity used, but does not include tax or shipping.

EMP Shielding	5052 H32 Aluminum Sheet, 24" x 36" x 0.02" thick	1	www.OnlineMetals.com	$10.33
EMP Shielding	Piano Hinge - item #030699151745	1	Home Depot	$7.47
EMP Shielding	3/16" Pop rivets - item #045731124038	Pk	Home Depot	$5.98
Sub-total:				$23.78

CONNECTION & CONTROL PANEL

This panel is made from scrap Plexiglas. Please note that you may need to adjust the dimensions to match the actual parts you use and how much space you have on your control panel. These dimensions are all based upon the parts I used in this book, but other parts might require different dimensions.



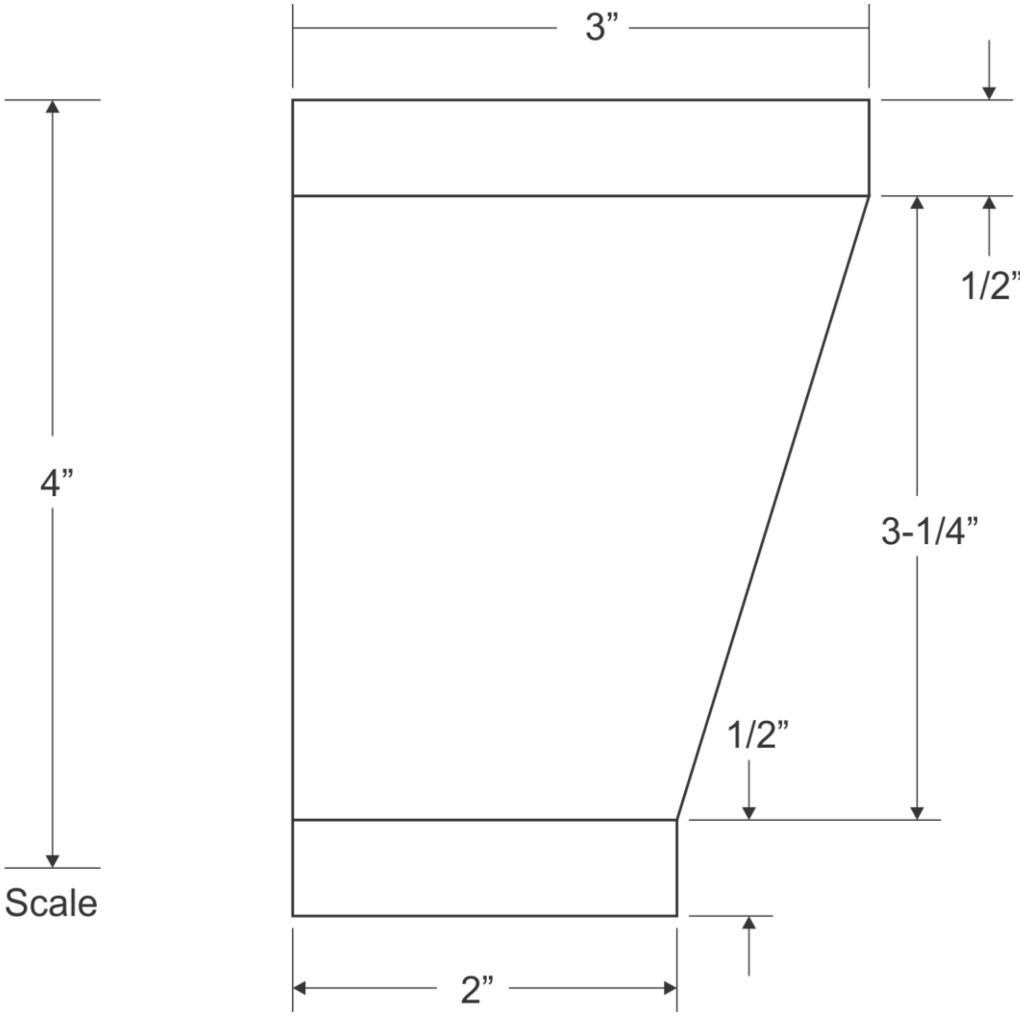


Notes:

- Blue lines are outlines of the parts, for reference only
- Red lines are there to mark where the center point is for drilling. I recommend using a center punch to mark these locations and then drill
- If you have enough material, you're better off making the flanges of the C larger. That way, they will help protect from accidental shock

CONNECTION & CONTROL PANEL SIDES

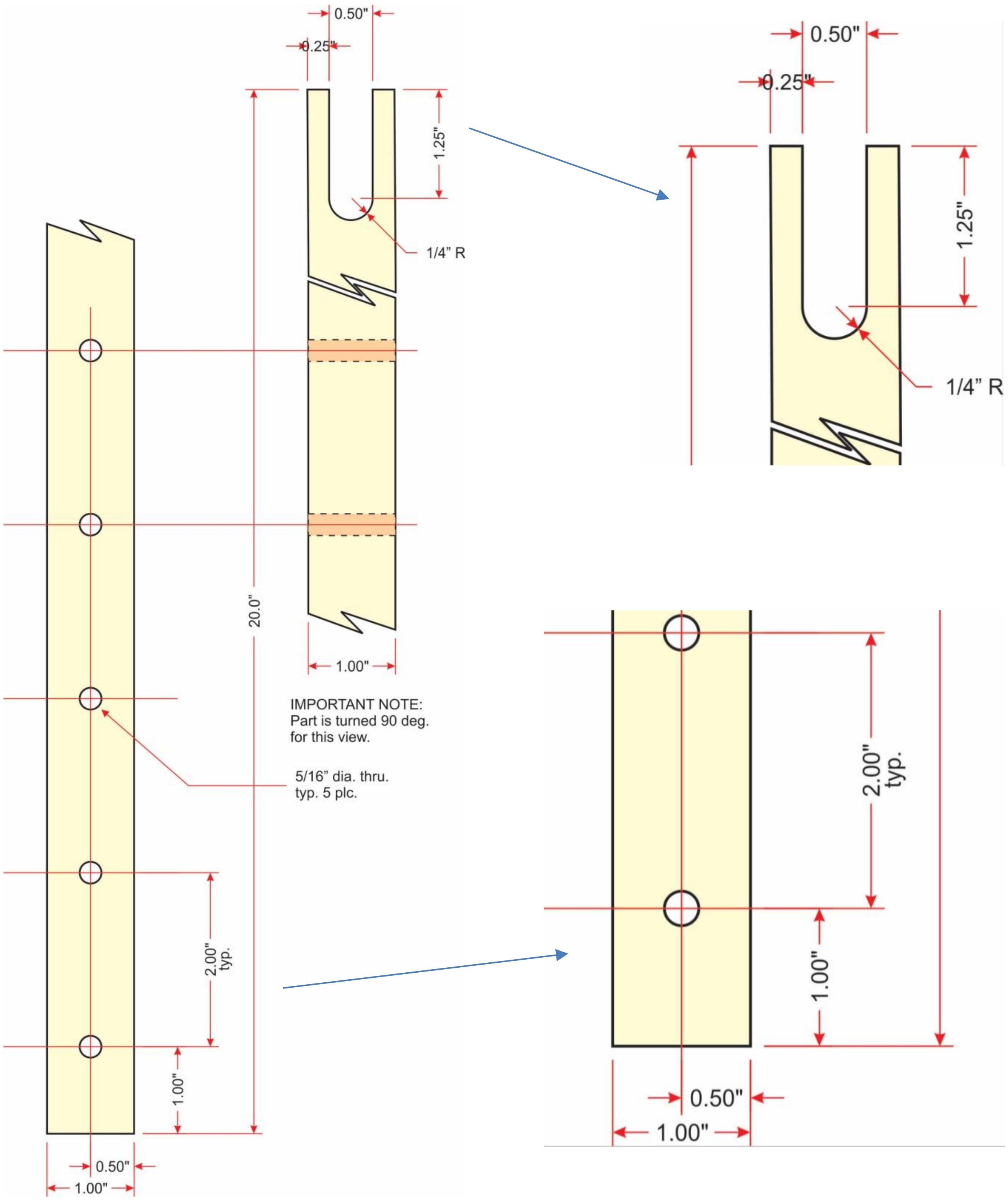
This is not a requirement, but I've added it to my backpack power unit to add strength to the connection & control panel and prevent any accidental shocks from fingers getting into the connections.



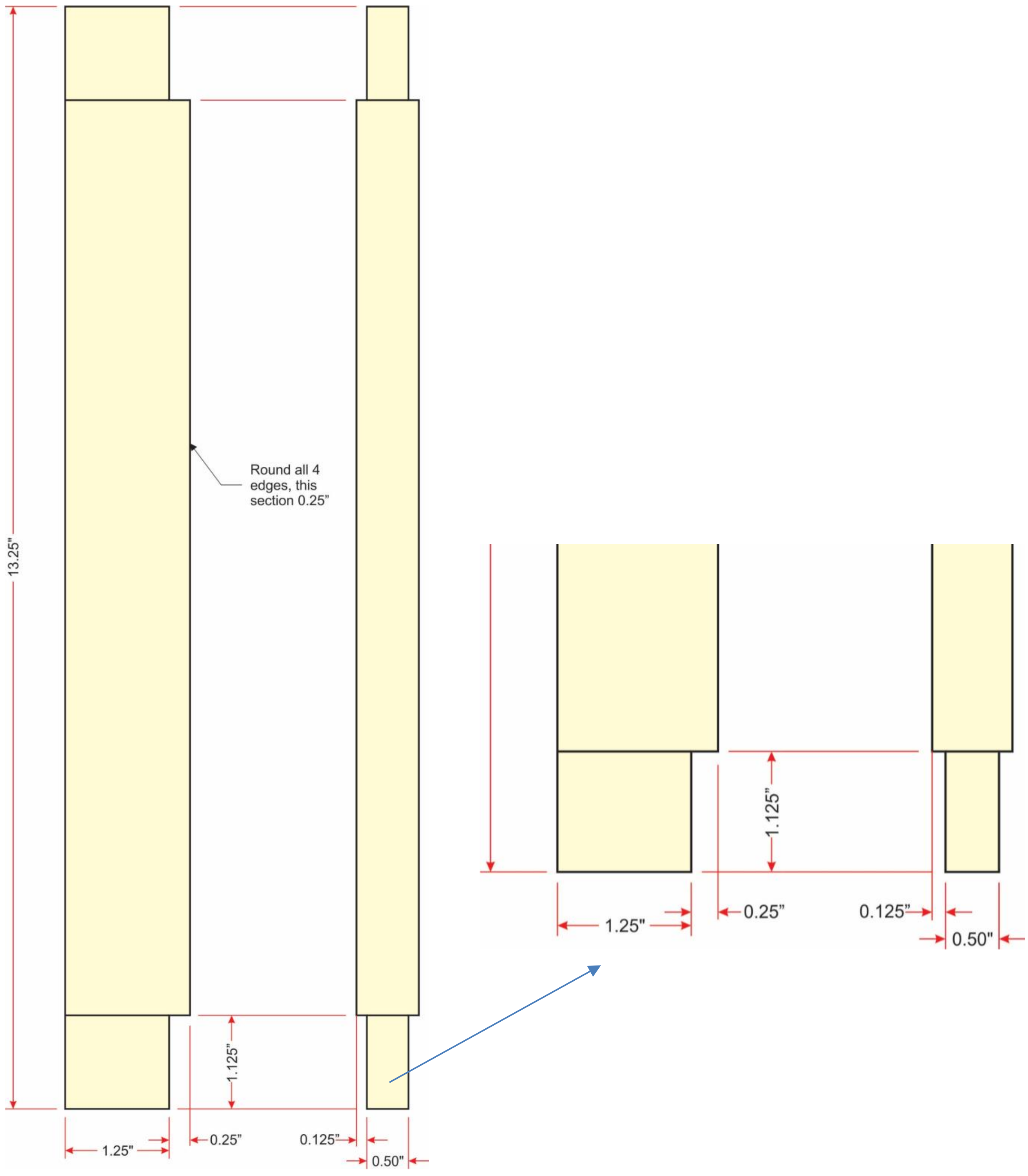
Please note that you need one of these with the tabs at the top and bottom bent up (towards you) and the other with the tabs bend down (away from you), so that they can go on the two ends of the connection and control panel.

You may need to adjust the dimensions, depending on the dimensions of your connector and control panel.

HANDLE UPRIGHTS FOR USE WITH WHEELS - WOOD BACKPACK FRAME



HANDLE CROSSBAR FOR USE WITH WHEELS - WOOD BACKPACK FRAME

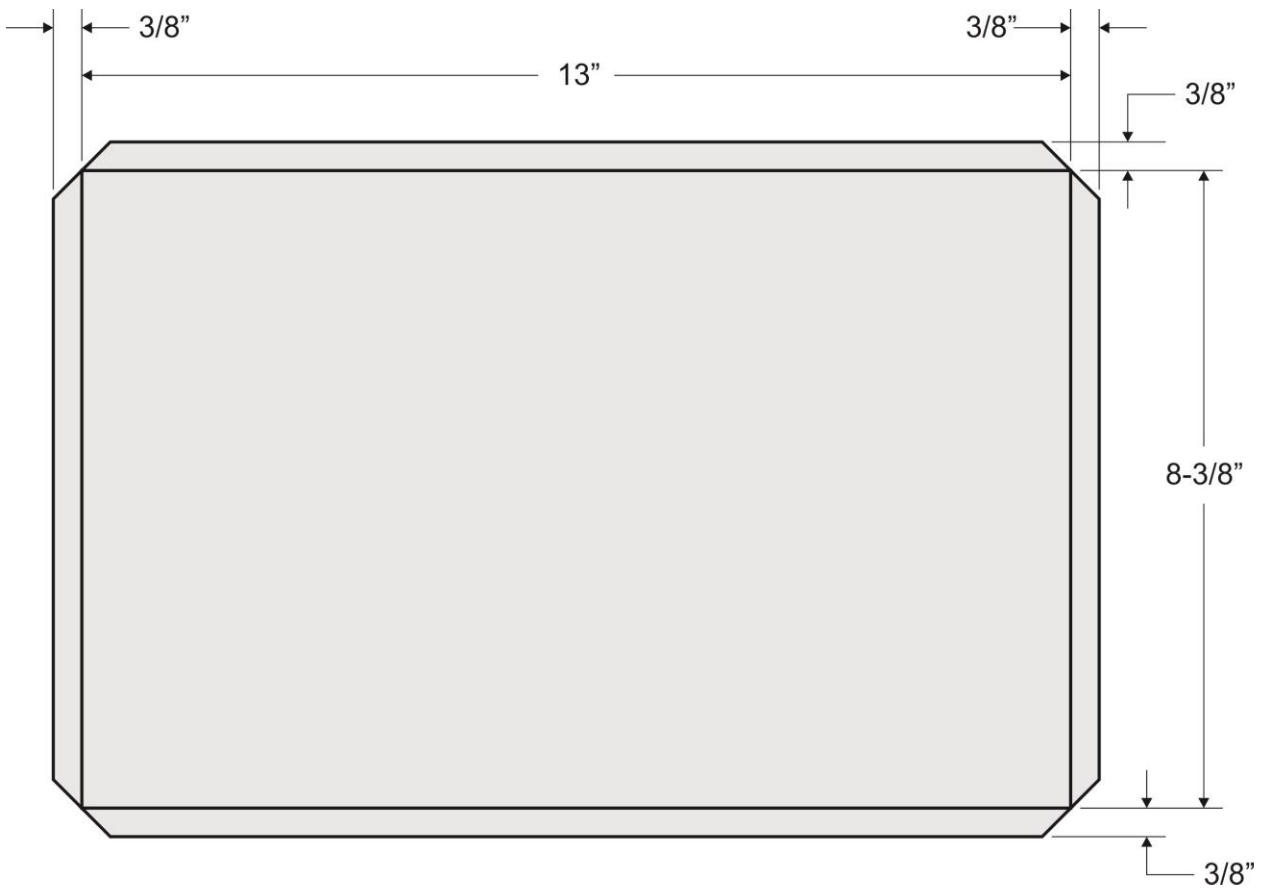


Notes for Handle for use with Wheels - Wood Backpack Frame

- Two uprights are required, but only one crossbar.
- Uprights are made of 1″ square hardwood dowel.
- Crossbar is made of 1″x 2″ select pine. You can use a lower grade of pine, but will need to cut a section without knotholes. If you leave the knotholes in, it will be harder on the hands of whoever is pulling the unit.
- The string of five holes in the upright are for mounting it to the wood backpack frame. This allows three different height adjustments. The holes are intentionally oversize at 5/16″ for the 1/4″ thumb screws being used to attach the two together.
- Relieve the edges of the mounting holes slightly with a countersink to avoid chipping of the wood.
- When you install the threaded inserts into the wood frame, make sure you put them flush or below flush with the surface of the wood. Level the edge of the hole with a chisel, as it will rise slightly from the rest of the surface.
- IMPORTANT NOTE: When looking at the drawing for the uprights, the section on the right is at 90 degrees to the section on the left. This will make the mortise visible from two opposite sides, where the mounting holes are not visible. You shouldn't be able to see the mounting holes and the mortises on the same sides of the pieces.
- Centering of the 1/2″ holes in the uprights for the mortises is fairly critical, as it will affect the positioning of the mortise.
- Cut with care, when cutting the mortises and tenons. Your cuts need to be straight, so that they will align properly and you'll have good gluing surfaces. But if you are off a bit, make sure they fit anyway. The dowel pin will hold the parts together, even if you have gaps. Fill the gaps with wood putty and nobody will be the wiser.

EMP SHIELDING - BACK

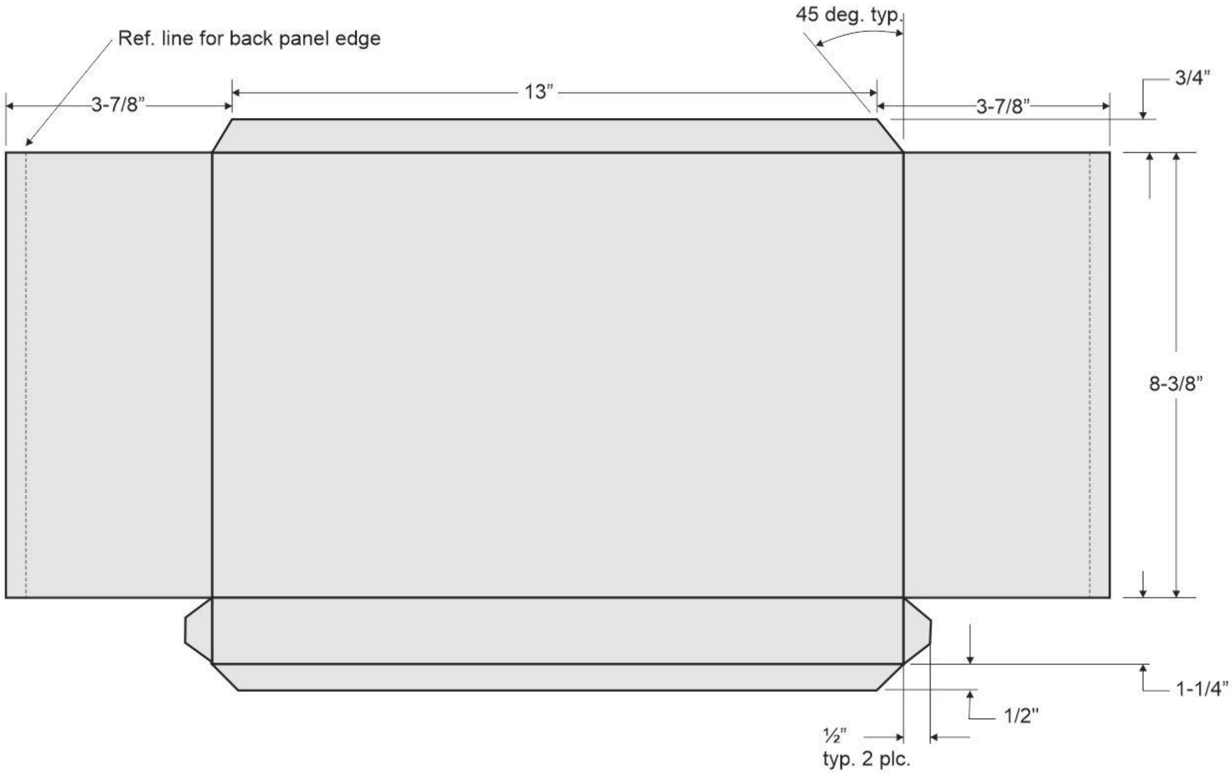
This part is made out of 24 gauge aluminum sheeting. The only lines to be cut are the exterior. The rest of the lines are bend lines.



Please note that the dimensions are taken from the backing board on my backpack power unit. If your backing board is larger, you'll need to adjust the dimensions accordingly. Likewise, if it is thicker, you'll need to increase the size of the flanges from 3/8" to match your backing board's thickness.

EMP SHIELDING - FRONT

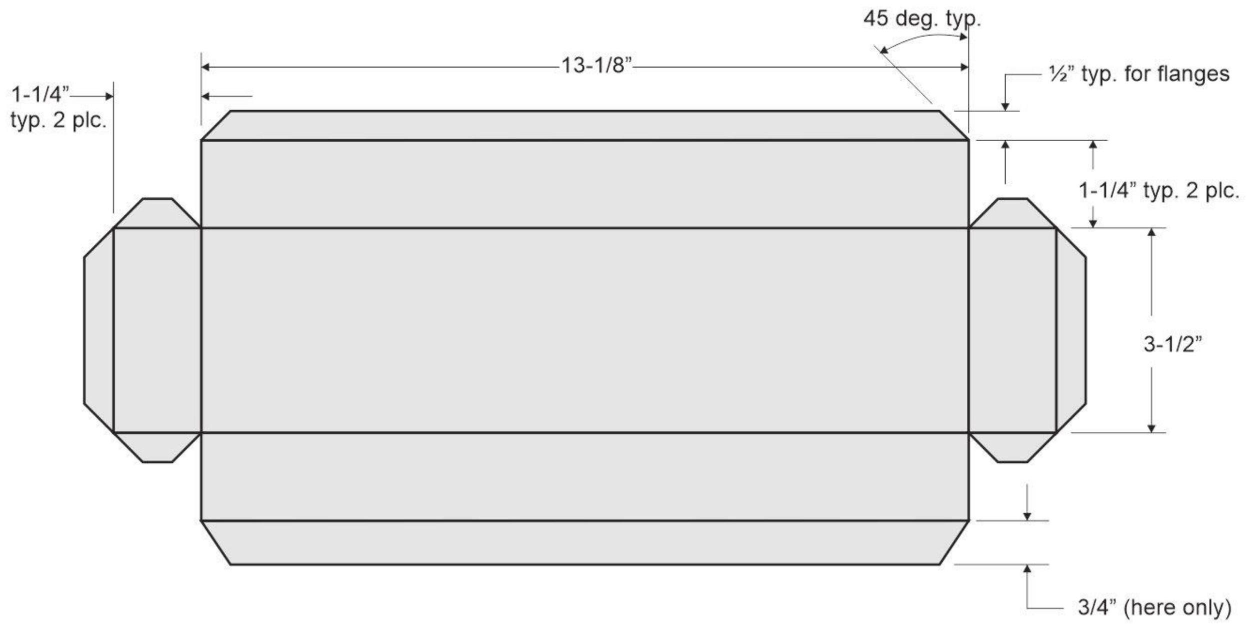
This part is made out of 24 gauge aluminum sheeting. The only lines to be cut are the exterior. The rest of the lines are bend lines.



Please note that the 13" and 8-3/8" dimensions are based on the size of my backing board. If your backing board is larger, you'll need to adjust these dimensions accordingly. The 3-7/8" dimension (2 places) is based upon the height of the connection panel and the thickness of the backing board. If your connection panel is more than 3-1/4" high or your backing board is more than 3/8" thick, you'll need to adjust these dimensions.

EMP SHIELDING - LID

This part is made out of 24 gauge aluminum sheeting. The only lines to be cut are the exterior. The rest of the lines are bend lines.

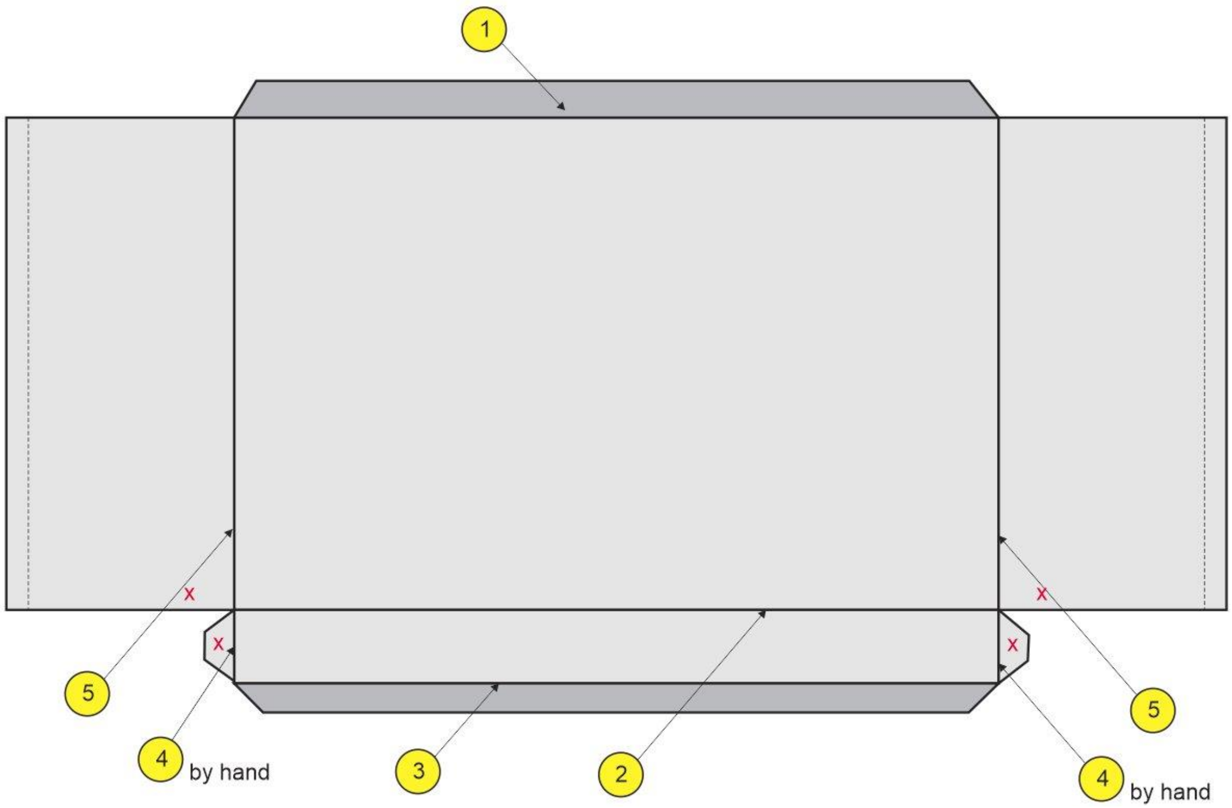


Please note that the 13-1/8" dimension is based upon the width of the backing board. If your backing board is wider, you'll need to adjust this dimension. It is purposely wider than the front part of the EMP shielding, so that it will overlap it slightly on both sides.

EMP SHIELDING - BENDING ORDER

The diagrams below show the order in which the bends should be made in the front and lid of the EMP shielding, so that one bend doesn't get in the way of the next. The darker shaded areas are to be bent 180 degrees, forming stiffeners for the parts. All the rest of the lines are to be bent 90 degrees.

Front



Note: The red Xs on these drawings are to indicate the hole locations for the rivets to attach the pieces together, once bending is complete.

Lid

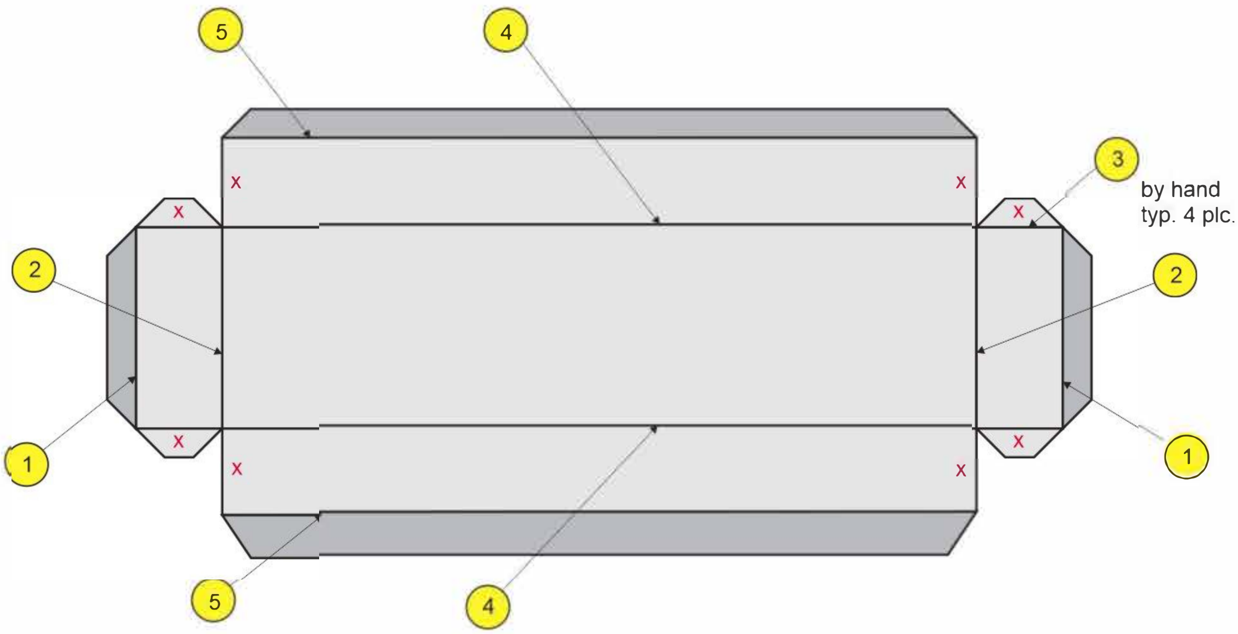


TABLE OF WEIGHTS

I've shown you various configurations of the Backpack Electricity system in this book. One question that might be floating around in the back of your mind is "How much does this all weigh?" That's a good question. Let's take a look at the weight of the various components and options.

Configuration	Weight
Basic unit - without backpack [11]	6 lbs. 3 oz.
Unit on wood backpack frame - with original battery	13 lbs. 11 oz.
Unit on metal frame - with original battery	15 lbs. 12 oz.
Unit on wood backpack frame - with car battery	44 lbs. 2 oz.
Unit on wood backpack frame - with Li-Ion batteries	11 lbs. 4 oz.
Unit on wood frame - with original battery, EMP shield and rain cover	19 lbs. 15 oz.
Full-sized solar panel	10 lbs. 2 oz.
Folding solar panel	14 lbs. 3 oz.

Here are the weights of individual components, if you need to adjust the above weights in any way.

Item	Weight
Wood backpack frame	3 lbs. 7 oz.
Metal backpack frame	5 lbs. 8 oz.
Backing board with connection panel	2 lbs. 2 oz.
Solar charge controller	5 oz.
Voltage inverter	1 lb. 12 oz.
Belt & straps	1 lb. 2 oz.
EMP shield	13 oz.
Rain cover - with support	9 oz.
Small battery	4 lbs. 9 oz.
Car battery	35 lbs.
Li-Ion battery packs (3)	2 lb. 2.4 oz.

[11] Backpacks themselves vary extensively in weight. Therefore, I've left that weight out.