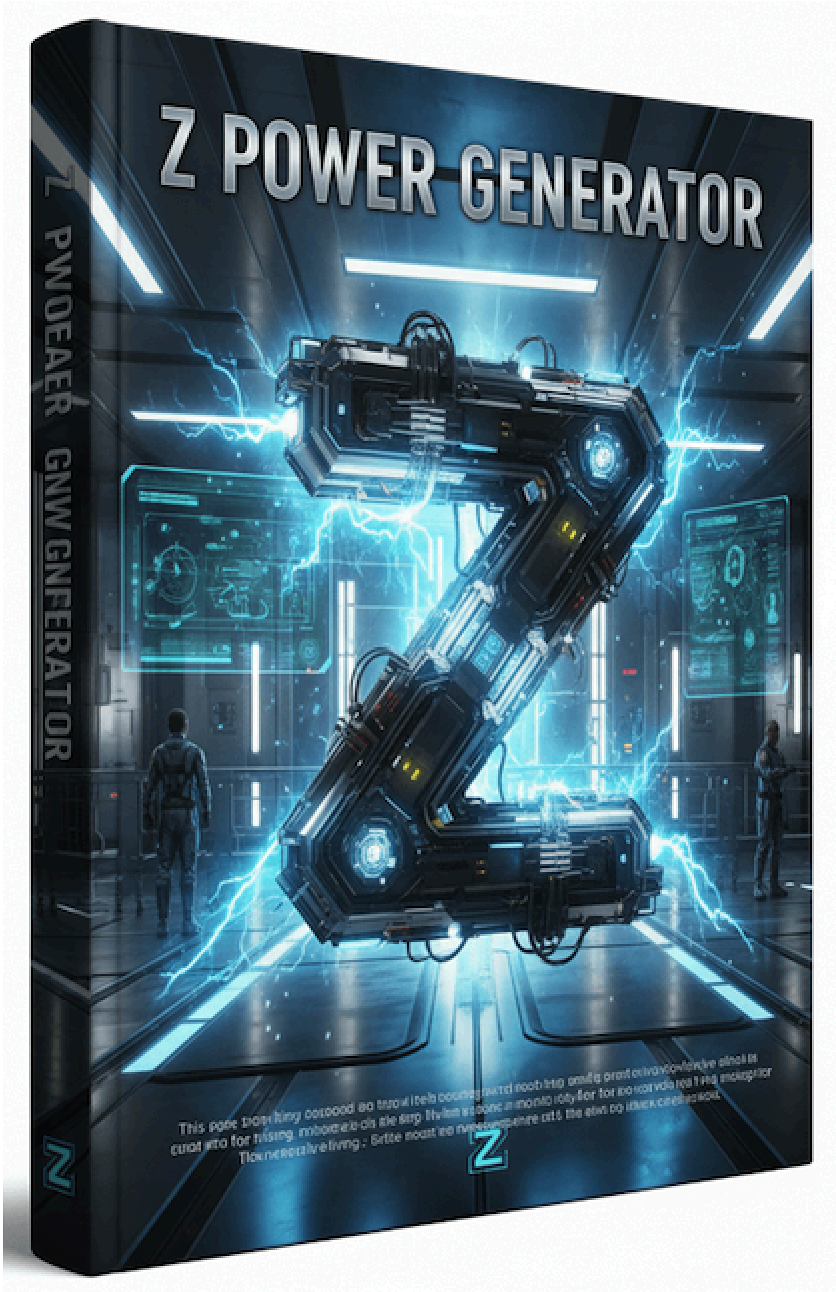
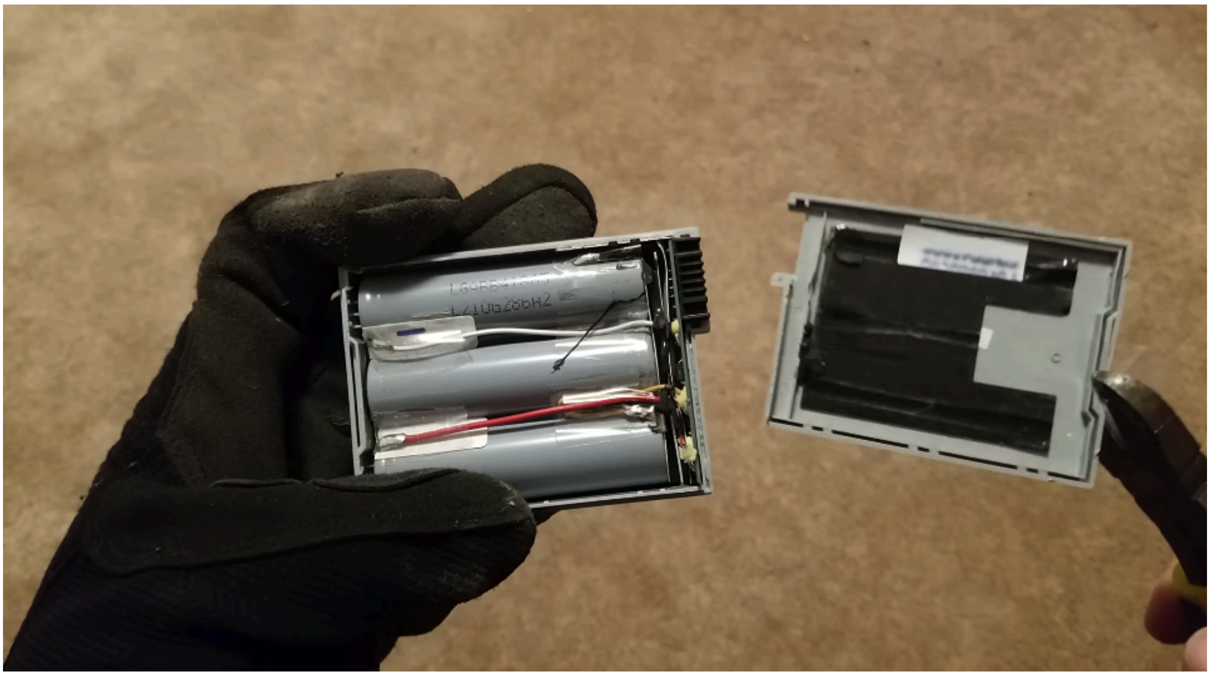


Today, I'm going to be tearing this Craftsman tool box into a three-and-a-half kilowatt-hour DIY solar generator. So, I picked this toolbox up at Lowe's. I think it was about 25 bucks. It's definitely heavy-duty. It's very spacious inside. There's a lot of room to work within here.

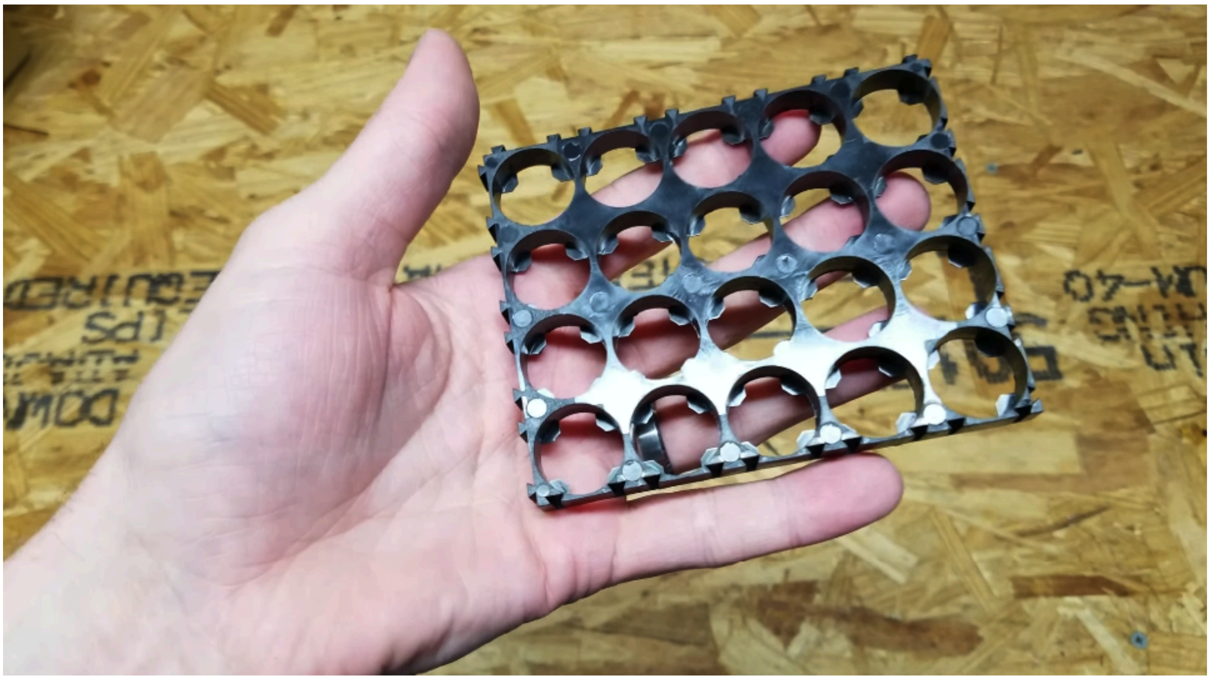
So, I debated for quite a while what kind of batteries I was gonna use in here, and in the end, I decided to go with the standard 18650. So, I'm gonna build two packs in a 14 by 13 configuration, and there's just enough room here that I can fit 13 cells in this direction and 14 cells wide. It would have worked out a lot better if I could have fit 14 cells in this direction because then I could have worked more in this direction. But these are the batteries I'm gonna be using for the project. These are from some kind of modem. There's 130 batteries here, which comes out to 390 cells. They should be 2600 milliamp-hour cells. They're currently on sale at Battery Hookup for a dollar fifty per pack.

Alright, so the best way to open this is just to take the two corners facing away from the terminal, and you want a big pair of wire cutters and just snip into those corners, and the lid should pop off. It's very easy, and there's your three cells inside. Then, you can use a common screwdriver to pop mufe you want, but the way I've been doing it is with some long-nosed pliers, and just grab the PCB like this and pull out, and then your cells come straight out. Now, I just have 129 more to open.



These cells ended up testing a lot better than I was expecting. I knew they were gonna test good, but I didn't know they're gonna be this good. So, out of 390 cells, there wasn't one single bad cell in this lot. Almost all of them tested in the 2500, 2600, or 2700 milliamp-hour range on average. The gray cells did test higher than the purple cells, so that actually gave me some extra cells left over. Only 11 fell outside that range, and they're not even bad cells. There's some 2421; you know, they just have a slightly lower capacity. So, I was able to pull out these 11 cells that were below the 25 threshold.

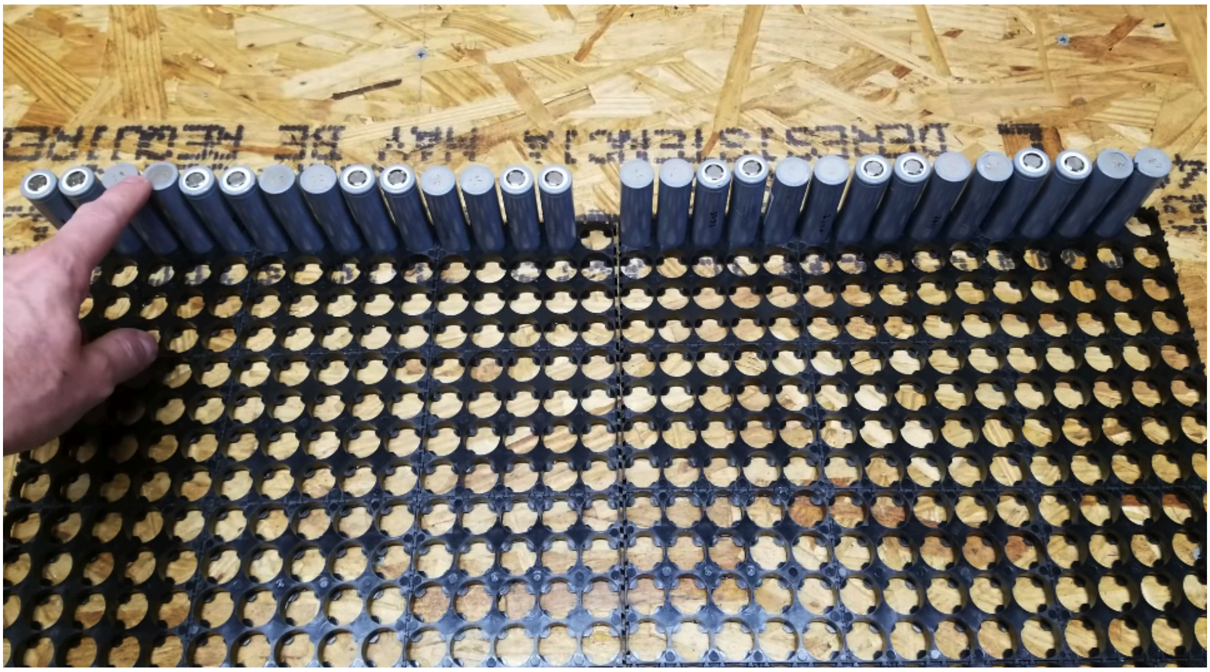
So, I'm gonna separate the gray and the purple cells just to make sure I can get an even distribution in each series pack. Now that cells are separated, we can begin assembling our battery packs. For this particular build, I decided to use the standard 4 by 5 18650 cell holders. However, there are also these honeycomb designs, which lessen the amount of space between each cell. These holders will allow you to get a more energy-dense configuration, and I did calculate you can fit up to four and a half to five kilowatt-hours in that toolbox if you were to use the honeycomb cells.



Now, while a four-and-a-half to five kilowatt-hour battery pack would have been preferable, there are two reasons why I'm going with this design instead of this design. The first being that the holders and the nickel strip for this design are just a bit cheaper. And the second being that if you put four and a half to five kilowatt-hours in that toolbox, it's gonna be way too heavy, and there's no wheels on it or anything like that.

Now, these holders actually measure 13 by 15. So, when I populate these cell holders, I'm gonna leave the rightmost lane empty. You could go with a hacksaw or coping saw or whatever and cut that off, but considering it's only about a half an inch of space or so, I'm just gonna leave it in place.

So now, because these cells are all from the exact same source and they're all of similar capacity, I'm just going to use the randomized method of populating this and just fill them straight from left to right. I'm not gonna worry about using repack or anything like that to get the capacity similar, and because the gray LG cells did test a little higher than the purples, I'm gonna start populating with those first.



Now you'll notice, when I populate these cell holders, I have every grouping of two in the opposite orientation as the previous one, and I'll explain why that is when I get to the spot welding step. But first, I need to get all these boards populated, and I'm gonna do it the same way lengthwise as you see in the first row.

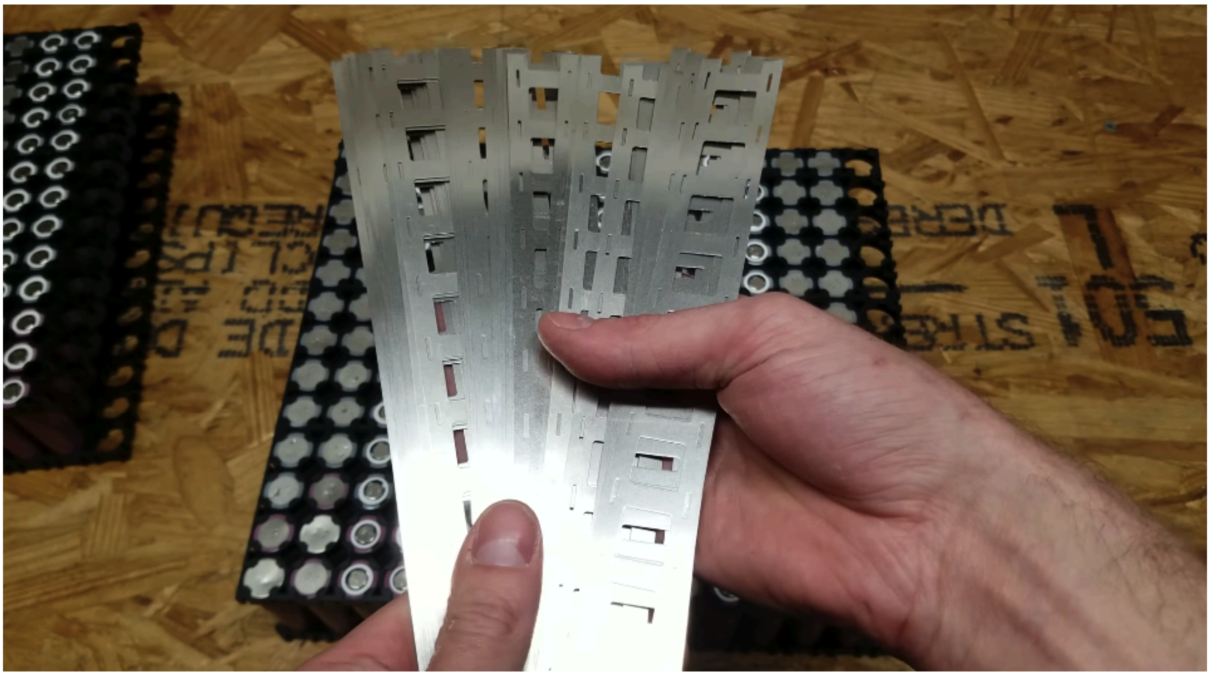
Alright, so now these cells are in the holders. It's a little easier to explain why I chose to lay them out this way and how the configuration is going to be set up. So, I have 28 rows of cells total here, and every other grouping of two, the polarity is reversed. So, this is going to be a 14S26P battery. Each grouping of cells of the same orientation is going to be wired in parallel, and then each of these parallel sets are going to be wired in series.

So, to do a little math here, we have 26 cells in parallel times 14 sets; that gives us 364 cells. So, one cell is 3.7 volts nominal times 2.6 amp-hours; that comes out to 9.62 watt-hours per cell. Times 364 cells will give us 3501 watt-hours of storage. Now, we have 14 cells in series, and the nominal voltage again is 3.7, so they'll give us the system voltage of 51.8 volts nominal, so it's slightly above 48.

So, before we put the top in, just double-check to make sure all the polarities are correct.

Alright, so here we have our two battery packs. Typically, when you're using recycled 18650 cells, there's a little bit of glue left on the wrapper and stuff left over that causes friction, so the cell holders sit on perfectly fine. However, these cells from Battery Hookup were so clean coming out of the packs, there was no glue on them whatsoever. That they're actually loose in these cell holders, so I'm gonna be very careful how I'm moving this around; otherwise, the lid is gonna come off and the cells are gonna go everywhere.

So, for the nickel strip, I'm going to be using 2P, and it's called 2P because it's two cells wide, 0.15-millimeter-thick nickel strip. This is pure nickel. I purchased this from Keith's store, which is where I get most of my stuff from, and he actually cut it custom to order, so I don't even have to spend any time cutting it. So, thank you, Keith. There wasn't even an extra charge for the cutting, and I really appreciate that.



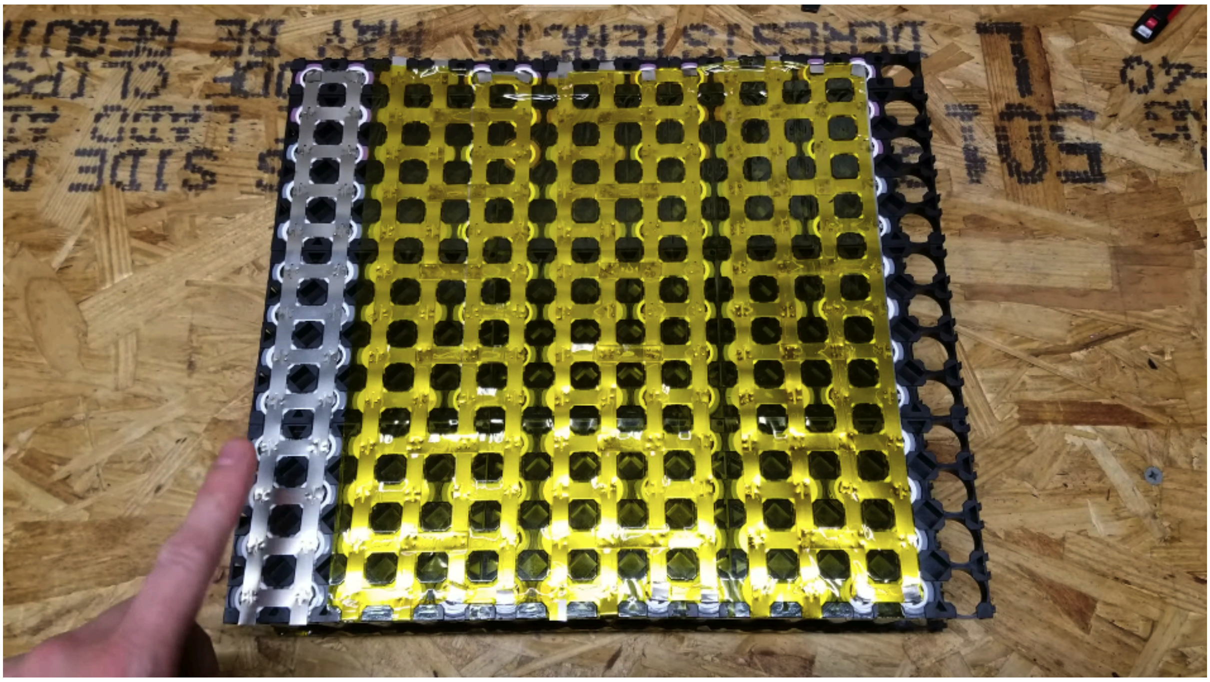
So, I'm gonna put one 2P strip up each parallel group. And then you may have also noticed how there is a slot in the nickel, and the reason for that is one probe of your welder is going to go here, and the other probe will go here, and this slot basically allows the current to go down through the cell and back up the other side rather than taking the path of short resistance and going straight across if this hole was not here.

Now, a much better design for this battery would have been to have 4P-wide nickel. That way, these two were connected in series, and I didn't have to connect them in series later. However, the layer of these batteries kind of changed from my original plan, and Keith nor anybody else in the U.S. that I could find sells the 4P nickel, and I didn't want to wait for international shipping from China, which could have taken a month or two.

So, what I'm going to do is weld the top and the bottom of each parallel set, and then I'm gonna put pieces of nickel going across every couple of cells to then connect them in series. But first, I need to get all the parallel sets spot-welded, and to do the welding, I'm going to be using my SONCO 70980 spot welder, that I modified with these custom electrodes because this is a 240-volt version, and I don't have any 240-volt outlets in my garage. I'm gonna have to take this in the house to get spot.

I have the welder set on a current of 7.5 in a pulse of 12. I laid the nickel over the first set of parallel cells and put one electrode on each side of the slot. Each cell will get four welds. Now, I do have this welder on a dedicated 20-amp circuit, but you can still see the lights blink each time I press the welder because of the instantaneous current it consumes. The lights and welder are both plugged into an inverter, not the power grid. You wouldn't see the same dimming if this were the power grid. And here's the finished product onto the next row.

Alright, so here's the first two battery packs all spot-welded up. This is the main positive bus bar. There are 26 cells here all wired in parallel, and then these 26 cells are wired in series with the next pair of 26 cells. And then the way I joined the 26-cell parallel sets is every other cell, I just put a piece of nickel across. And again, it probably would have been better to use 4P or four-wide nickel strip, but this 2P will work just fine.

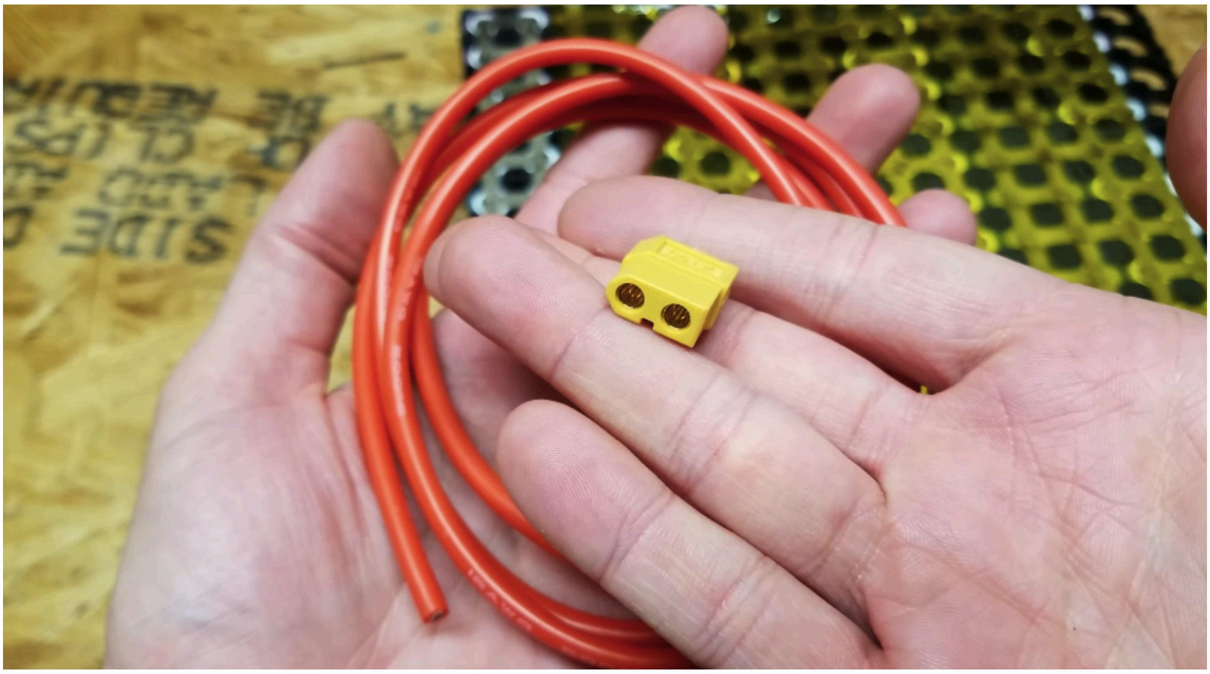


Here's just a little close-up so you can see what's going on. When I did these series connections, I did have to turn the spot welder up quite a bit to get a good weld. If you're doing something similar to this, one thing you have to keep in mind is as soon as you start making connections, this whole pack is live, and you don't want to accidentally drop a screwdriver or accidentally put a piece of nickel in the wrong location as you're working on this. So, you always want to double- and triple-check your connections.

As I was working across the pack with the spot welds, I was covering the areas I had finished with this Kapton tape, so that will prevent any accidents if a piece of metal were to fall on this battery pack or I leaned on it wrong or something like that.

So, on the back here, you can see the main negative. It's done the same way as the other side. So, we'll put a voltmeter on here quick. The main negative to the main positive measures 29.12 volts.

So, the only thing that remains to be done is to decide how to terminate the connections from the main positive and main negative. And to do that, I'm going to use some of this 12-gauge silicone wire. 12-gauge wire is rated for approximately 20 amps, and we're going to be drawing more than that from this battery pack, so I'm actually going to use two pieces of 12-gauge silicone wire on each end. Then, to make connections easier, I'm going to be using standard XT60 connectors. I'm going to use both terminals for the same polarities, and making these connections is very easy.



First, I'm going to put my XT60 in a vise. You can pretend this is a vise. Then, just strip off like an eighth of an inch of the insulation. Usually, good. Just twist the wires a little bit and slide a piece of heat shrink on each lead, and then just carefully insert the wire into your connector. I usually apply heat to the top of these and just carefully insert the solder from the back. Double-check that you got a good connection, and you're ready for the other side. Once your connections are good, you're ready to slide up the heat shrink.

Alright, there we go — a perfect connector. I'm going to connect this connector right in the middle of cells three and four from each end. This will give me equal distribution between both ends of the pack. However, I don't want to solder directly to this nickel strip that's already here and risk damaging the cells or the holders from heat. So, I'm going to take a separate strip of nickel and run out the entire length of this battery pack. I'm going to mark where I want to solder the leads. Just to help make this job a little easier and not burn my workbench, I just taped down this piece of nickel strip to an old piece of 2x4. You'll notice how I fanned out the end of the wire just a little bit. I'm going to place it on my mark, and when I attach that wire to the nickel strip, I used a common screwdriver just to hold it down. That's just to make sure the wire continues to make contact with the nickel as the solder hardens.

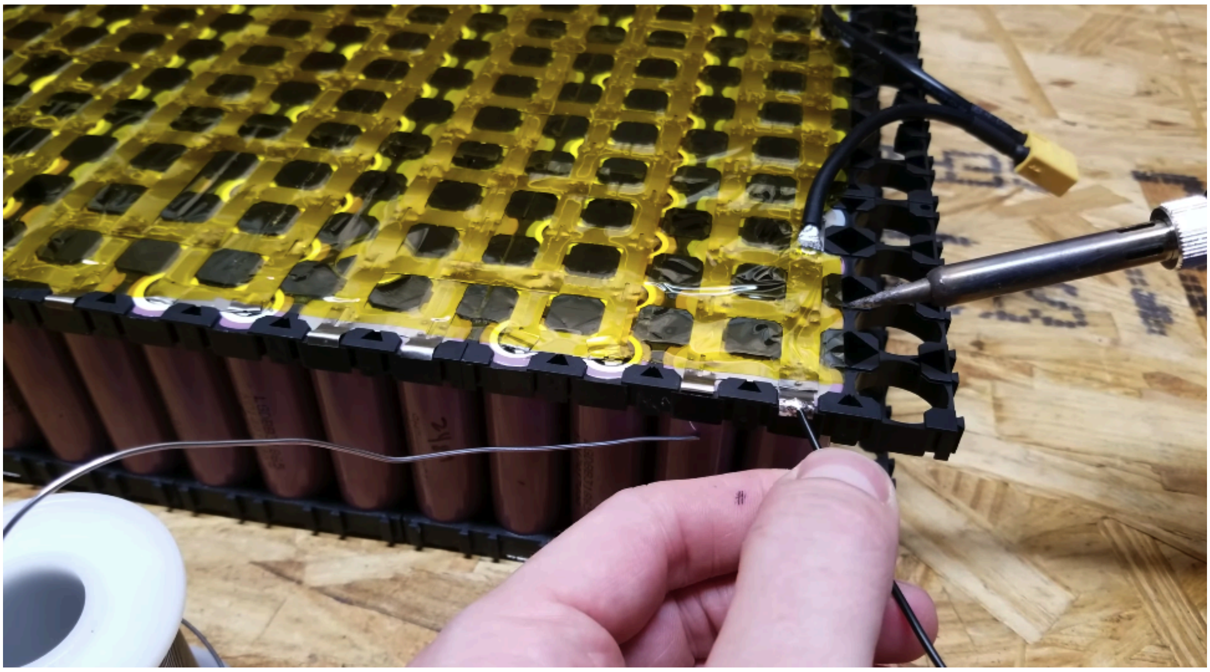
Now I just have to do the other side. So, now we can take this back inside, and we'll just spot-weld this strip into place. There is our connection. I spot-welded that strip on the side of my battery pack to splice on my connector, and it came out very well. Doubling up that nickel bar helps with the amount of amps that can carry along, while reducing the heat if I would have soldered directly on the existing tabs.

So, now if I stand up both of these battery packs next to each other, on the back here is where the series connection will be made between the two packs. There's just two XT60 to plug in, and if I take a reading with my voltmeter, now I have 58.2 volts. Now, I do have some heat-shrink I want to put over this, but before we get the heat-shrink put on, we need to wire the BMS.

For the BMS, I'll be using this Dahle brand BMS. It's a 14S48V BMS, and it has a maximum discharge current of 60 amps. There are multiple versions of the Dahle BMS. This one includes balancing functionality and also includes a common port. Common port means you have one negative lead that comes out. If this was not the common port model, you would have one negative lead that goes to your charger, and a second negative lead that will go to your inverter.

So, this is the wiring harness that comes with it. You'll notice one of the leads is black. We're going to start with the black lead. This is going to go to the main negative of the battery pack, and then we'll work our way up the string with the reds. After the main negative, this will go to the first cell, the second cell, the third cell, etc., all the way up until the last red will go to the main positive of the battery pack.

So, we're just going to solder this at the top of the battery pack and use these little bits of nickel left over at the top. I'm going to tin the nickel a little bit first, and this nickel is resting on this plastic, so you want to make sure you're not heating this up too much and melting that plastic. Looking at our wiring harness, we connected the black already, and this is the next wire in order.



Because our black wire is connected here, the first red is going to go on the other side of the cell. So, we need to flip over this battery pack. To avoid the constant flipping, I'm just going to work on it in the upright orientation. Alright, now we have these two attached. We're going to go on to the next wire. So, it's going to go on any of these terminals because this is the third connection.

Once you finish attaching all of your BMS leads, you'll have something that looks a little bit like a spaghetti mess. As long as you got all those connections right, you should end up with the last positive wire on the main positive of the battery pack. I was thinking I could shorten some of these wires and cut them to the length I needed so that way this was a nice clean bundle. However, one of my viewers in the last video commented about leaving the wires the exact same length, that way they all have equal resistance and the BMS is reading the cells equally.

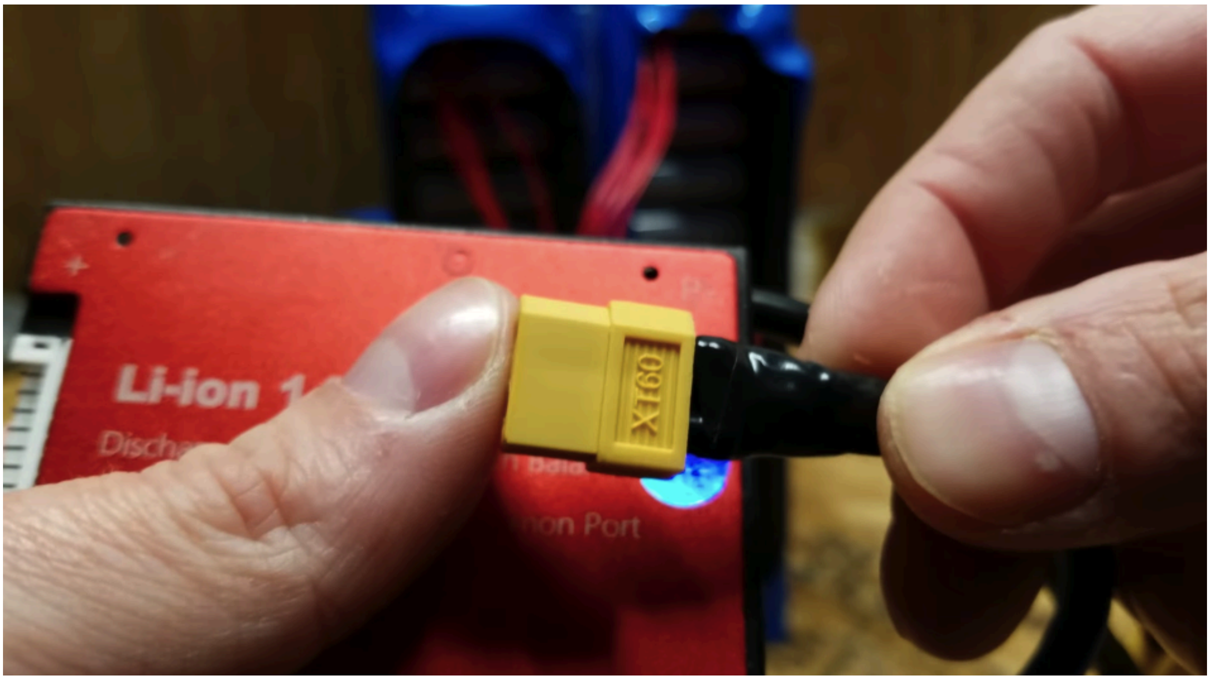
For security, no balance leads in the battery pack, I put down one layer of Kapton tape and used a second layer of Kapton tape to hold down the wires. That first layer of Kapton tape was just for extra protection in the event any of these wires or cells would heat up.

Now that we got our balance lead connected and our wires sneaking down, we're gonna heat treat each of these batteries with this giant heat shrink. This heat shrink is designed for a 15Y battery pack, and this is only a 13Y battery pack, so I'm hoping this will shrink down small enough. If not, we may have to purchase a smaller size. For the shrink, I cut it about ¾ of an inch large in the battery pack on each end.

Alright, so here's the completed pack once the heat shrink is on. That full package definitely does give it a nice look. Now, it would have been nice if there was shrinking enough to go around the entire pack. Instead, having two separate packs — I don't think there's one made that's big enough for that. So, I'm just going to slide this piece of plastic insulator in between the two packs. That will prevent the area where these connectors are soldered on from being squished in between, and then I'll just use a few wrappings of Kapton tape to hold the packs together.

One last thing before we can put this battery pack in our toolbox is we need to attach the BMS. The BMS has two negative leads: one is marked P- and one is marked B-. The blue lead marked B- is going to go to the negative terminal of your battery bank, and the black lead marked P- is going to go to your inverter and charge controller.

On the battery negative, I just attached a standard XT60 connector. On the power side, for the inverter and charger, I am using an XT90 connector because I wanted to use a bit thicker wire. Ten-gauge wire will not fit in the XT60 connector, and 40 to 45 amps is probably a lot on the high side for an XT60.



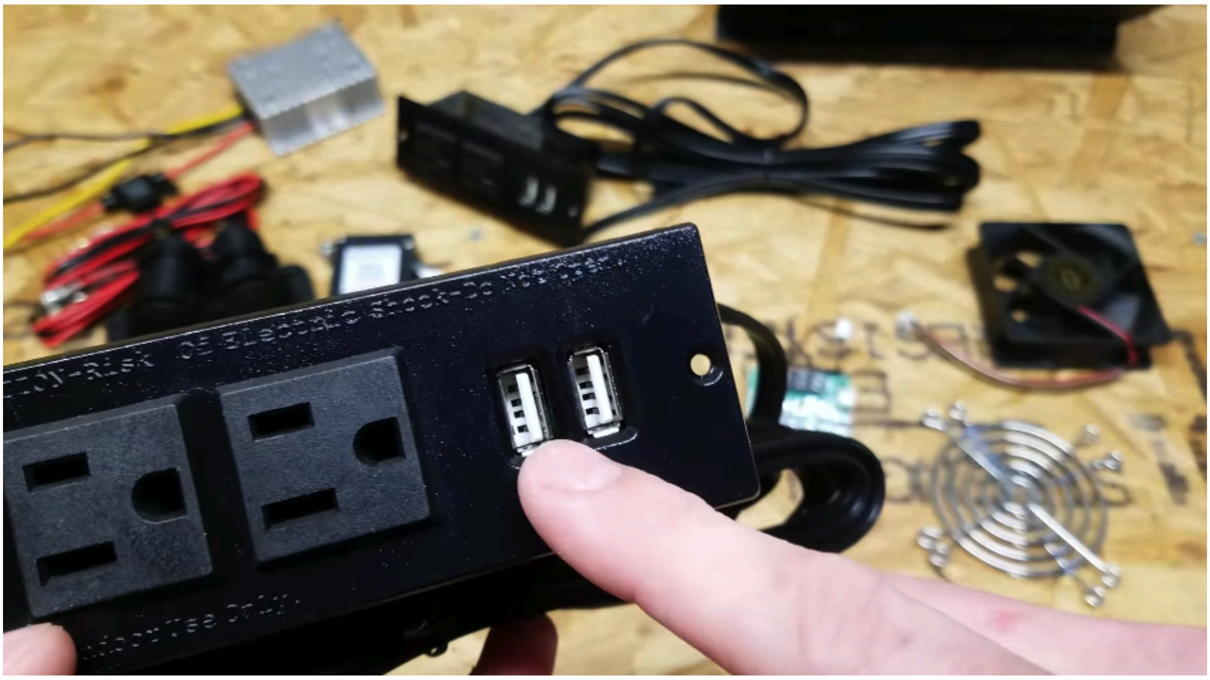
First, I'll plug the negative lead in. Then I want to mount it just like this, and I'm just going to use some zip ties to hold it down. With the BMS attached, now we can plug in our balance connection. Lastly, we'll plug in our positive connection.

Alright, we should see full pack voltage in this connection now, and we're at 58.1 volts, so we're good to go. For the remainder of this video, I'm going to explain why I picked each component and then show you how they're wired at the end. I'm not necessarily going to include all the drilling, layout, and assembly process because this video is already 20 minutes long, and the primary reason for this video was the battery build and the choice of equipment.

At the heart of this build will be a Reliable Electric pure sine wave inverter. This is 48-volt, 1500-watt. You can see there are two battery lugs in the back. In the front, we have two standard 115-volt outlets and just an on/off power switch.

I already had this inverter from a previous project. If I was purchasing a new one, I would still go with Reliable Electric because they are low cost, and as the name states, they are fairly reliable. The only difference I would have done is I probably would have gone with the 2000- or 2500-watt version.

For the output connection on the generator, I went with these recessed outlets. Each one is rated for 12 amps at 125 volts, and they have T receptacles. I have a total of four receptacles installed, and each one also includes two USB charging ports. They come with a fairly lengthy cord, and I obviously don't need more than a foot or so of cable, so I may try taking this apart and see if I can shorten that cord or not because I really don't want all this bulk in a toolbox if I can help it.



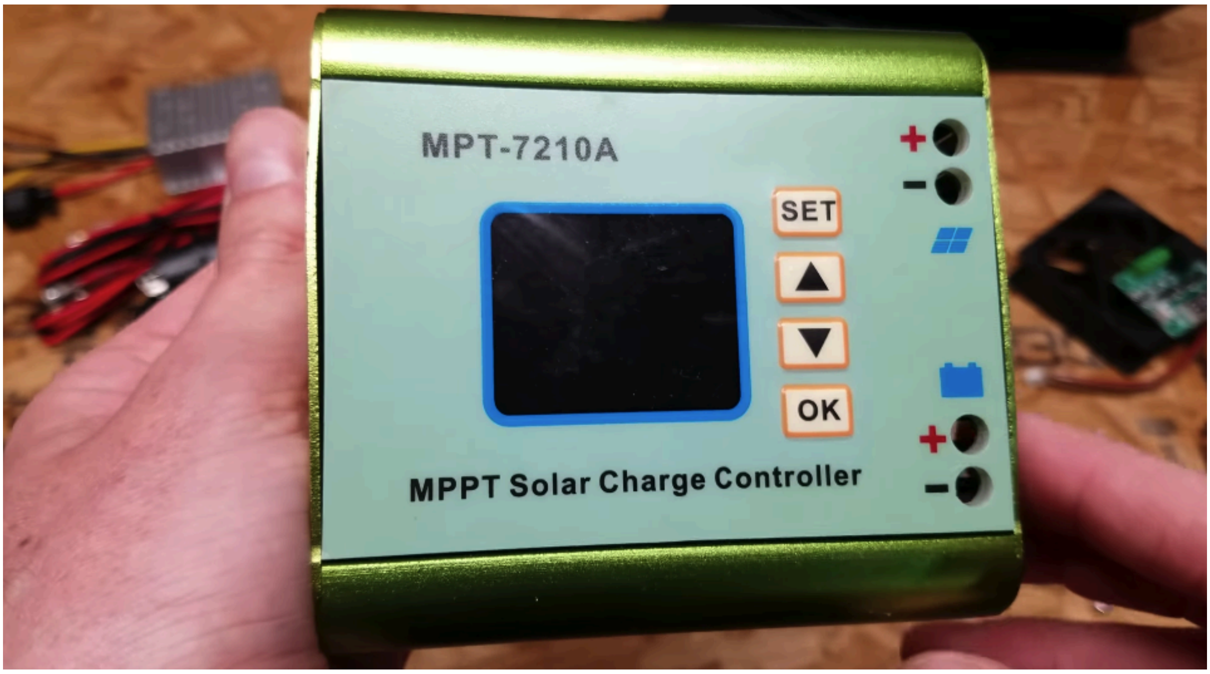
For the user interface, I went with this Drock brand energy meter. The voltage supply is good for 5 to 90 volts DC, and it has a maximum rating of 200 amps. Because we all need 12 volts in our system as well, this is a fairly standard buck converter. This is good for 240 watts. It will take in 36 or 48 volts (I forget the maximum tolerance — I believe it's like 62 or 65 or something), and it will output 12 volts DC at 20 amps. The 12 volts will feed into two standard 12-volt outlets. These are the first standard cigarette lighter plugs like you would find in any automobile.

Additionally, that 12 volts will feed into this temperature fan controller. It's just a small PCB that you can set a preset temperature on, and it comes with a remote temperature sensor. Once you have a set temperature on this board, it will control this standard 80-millimeter case fan from a computer to ventilate the toolbox and ensure it stays cool.

The main on/off for the toolbox will be this Blue C-Systems 50-amp circuit breaker. I am questioning whether or not I can use this, though, because I see it says that the UL rating on it is for up to 32 volts DC. However, I noticed that the max voltage listed on it is 65 volts DC, and on the website for Blue C-Systems, it also includes an interrupt rating at 65 volts DC. I did reach out to the manufacturer to see if I can use this for a 50-volt battery bank, and hopefully, I receive a reply fairly soon.

Last but not least, I'm using this generic MPT7210A solar charge controller, and I already have this controller from a previous project. One reason I chose this over other options available in the market is that this is really a DC boost converter. I don't think it's a true MPPT controller; however, I do like that this takes an input lower than your battery voltage. I can put anywhere from a 12-volt panel, a 24-volt panel, or, as a standard MPPT controller might take, 100 to 150 volts to turn it on.

Since this is a portable build, I don't want to have to carry around that many panels. I want to be able to take just one or two panels out, plug them in, and charge away. While this is not the best option in the market, it is the best option for my particular use case.



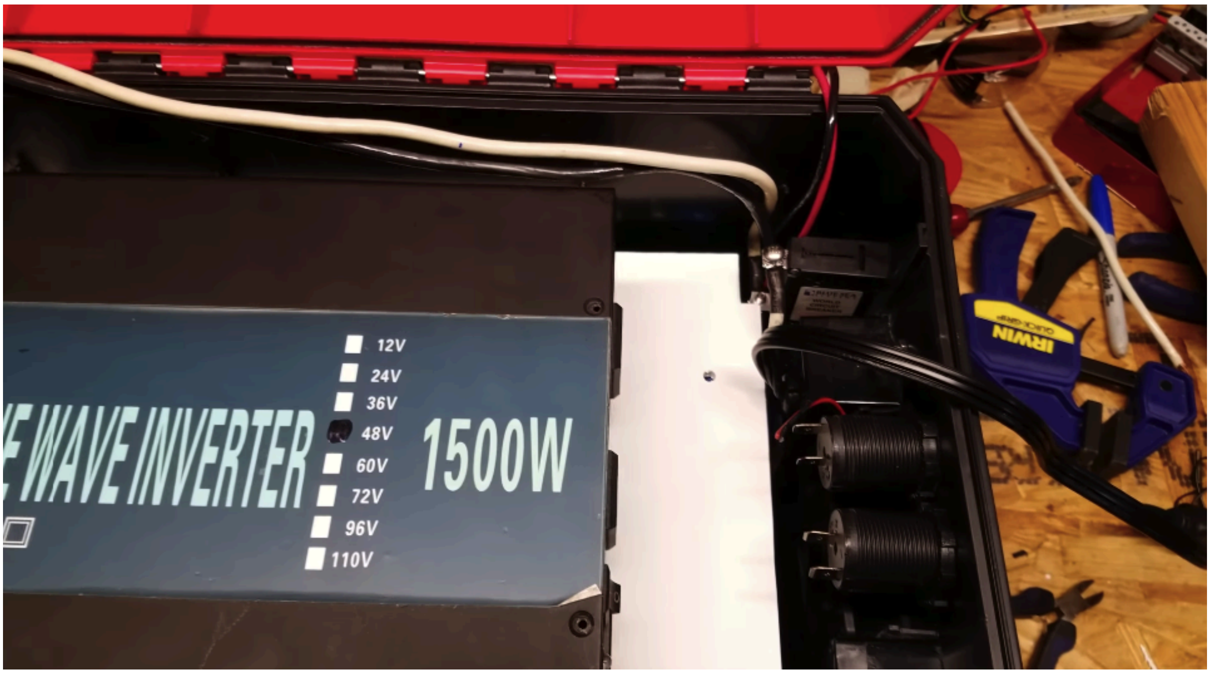
That's where I'm going to stop here at the video. I'm going to go ahead and get this stuff assembled, and then I'll review the wiring and how I set everything up.

So, I'm in the final stretches of getting this thing put together. Before I start closing it up where you can't see what's going on inside, I thought I would do a quick overview of where I'm at. On the right-hand side, I have almost all the components mounted, and I'll go over all of these later. For right now, just know they're on the right side. On the left side, I have a fan. The right-side fan is blowing air in, and the left-side fan is blowing air out. Airflow is in this direction.

On top of the battery, I just cut another piece of white plastic insulator that fits in like so, right on top of the battery. That gives us a nice insulated and flat surface to mount the inverter on, which will sit right here.

If you look down in there, I have four holes drilled on each side where I'm going to zip tie it into place. There is plenty of room for air circulation in the back, so the inverter will blow air out the back, and then it will get sucked out by the lower fan and the case down here. On the right-hand side, there's plenty of space for air to come up as well and get sucked in through the inverter. Most of the wires are going to be routed along the back. Back here, I still have to fit in the MPPT charge controller, which will likely sit down in here. I just have a little bit more fitting to do, so that's where I'm at.

I'm going to finish up the wiring, and hopefully, we can turn it on pretty soon. Alright, guys, it's finished, and it is great. I've done some basic testing with it, but I have not hooked up solar panels yet.

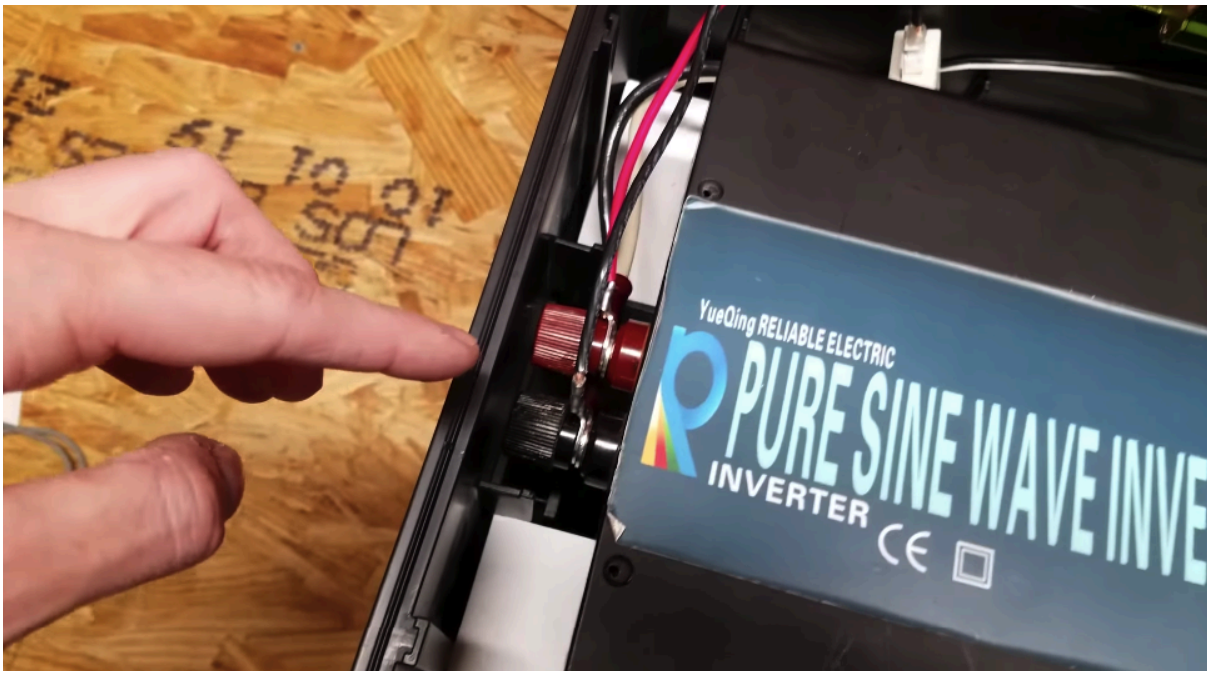


Before we do that, let's take a look on the side and see what we got. We have four 10-volt outlets. Each receptacle is good for 12 amps. There are two cigarette plug outlets, like your car charger stuff, which you might want to take out and use with a generator. There are four USB ports, each good for 2.1 amps of charging. There’s an XT60 connector for your solar input, or an AC-to-DC adapter can also be plugged in here. There’s also a 50-amp circuit breaker, which serves as our on/off switch.

I did hear back from Blue C-Systems, and they confirmed that this breaker is good for up to 65 volts. Once it's turned on, the display on top will light up. This basically shows the state of charge of the battery. I’m not really sure how it’s calculating this display, but it shows the current voltage, accumulative watt-hour display, and the amount of amps and watts being charged or discharged from the battery. It’s not super fancy, but it’s simple and gets the job done. That being said, it is not super accurate.

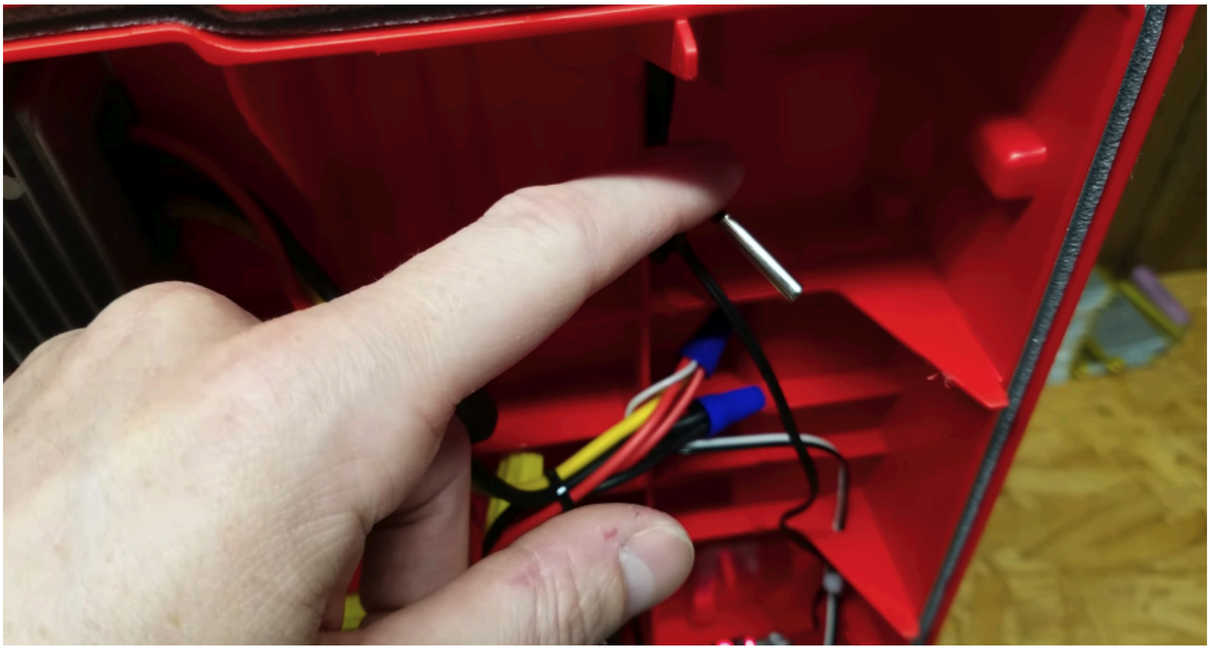
When we open it up, the main positive comes up out of the battery and goes into the battery side of the circuit breaker. The load side comes out at the bottom, and this positive lead goes all the way back to the positive side of the inverter. You can also see the negative lead coming up here as well; it bypasses the breaker. This is just a single-pole breaker. The negative lead goes over and connects to the negative side of the inverter.

On the inverter side, we have a set of red and black leads that come off as well. A pair of red and black leads comes up to the DC-to-DC converter. This steps down the 48 volts to 12 volts. A second set of leads comes off and goes down to the charge controller. Two other leads come off this controller and go straight down to the XT60 connector we saw in the front.



We have a black lead that comes off the 48-volt splice and goes into the Drock voltage display, and a red and yellow pair that comes off with a positive and goes into the Drock. This is good for up to 90 volts. If the voltage you're measuring was over 90 volts, you would have to supply one of these wires with a voltage within the acceptable range, and the other wire would be the sense wire for sending the battery voltage. Since our battery bank is under 90 volts, we can attach both of these to the same positive.

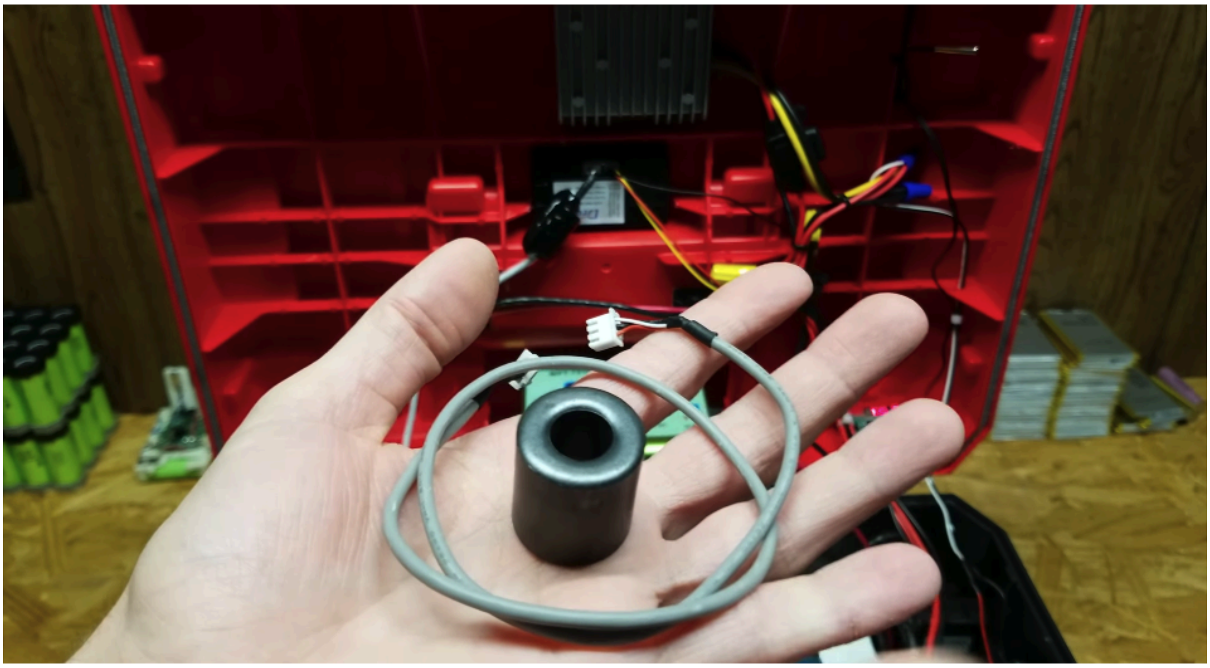
I did make a mistake — this is the 12 volts place, and these are the 48 volts places. The 12 volts that comes off the buck converter comes down to these two splices. One lead goes down to the fan controller. This fan controller is very cool. It might be difficult to see the display in the video, but it shows 16.7°C. You just use these buttons to set the temperature at which you want the fan to engage. You can switch any voltage within the range of acceptable voltage printed on the relay. I'm also switching 12 volts. I just have a little jumper lead going over to the input on the relay, and the output comes out to these two white leads, which go over to the fan. All three black leads are tied together on the ground lead. The last lead that comes off this board is the temperature sensor, which is just running up to the top, sticking off right over here to get a good reading away from direct airflow.



Additionally, coming off the 12-volt rail, we have both of our cigarette lighter outputs. They run down here. They are individually fused with 10-amp fuses. They come down to both cigarette lighter plugs.

Last but not least, we have the AC wiring from the AC outlets. I was able to open these boxes up and cut and route the cord. I've only got about a foot or a quarter in each one, instead of having the full 10 feet or whatever it was, rolled up and stuffed in here. I just tucked those underneath the inverter nice and sound.

One thing I want to mention about this Drock display is that the cable that came with it is very thin, two-conductor cable with a shield. The shield is used as the center ground pin, so it is shielded, but it's very susceptible to interference. Any time this wire ran along another wire, or even when the lid was closed and it was against the inverter, the display picked up all kinds of interference.

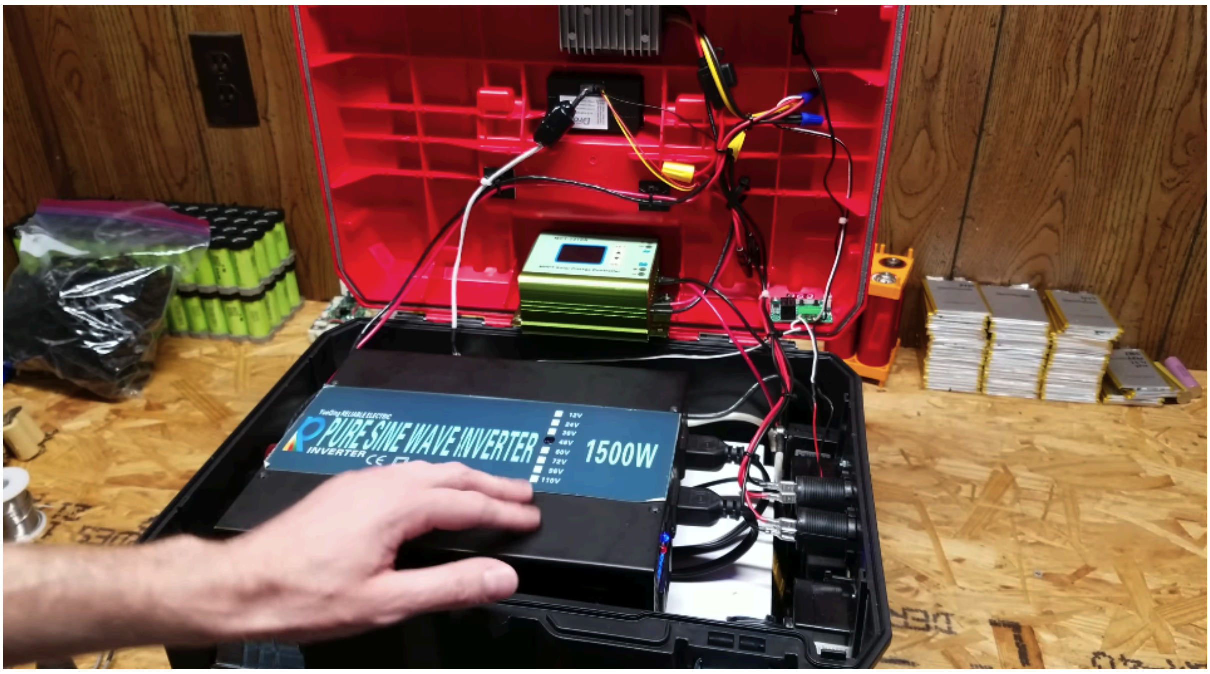


This display has a way to zero out the display to account for interference, but the problem is any time this wire moves, or the lid opens and closes, the amount of interference changes. First, I took this gray wire and ran it through a ferrite coil. That was actually an idea that Keith had given me, so thanks. That helped with interference, but it was still not perfect. I replaced this wire and made a new wire — aircraft wire, three-conductor, twisted and braid-shielded. I twisted it around three times (twice? no, three passes) through a smaller ferrite coil, clamped it down with heat shrink. Once I put this ferrite as close to the display as possible, it gave me a near-perfect reading. You can see where that wire attaches down here — it's just a little coil that your positive lead passes through, and that just sits there reading the amount of current using a magnetic field.

Yeah, that's pretty much an overview of the wiring on this thing.

Before we wrap this video up, I want to plug in a few appliances and test it out to see what it can do. It's windy and cloudy today, so hopefully tomorrow it's bright sun, and we can take it back and plug in some solar panels.

Oh, two more things I want to mention. First, if you don't have fan holes cut and you're not going to use fans for ventilation, this is a watertight enclosure. It's very important that you remove — you can see a little gasket going along the outside of the case. It's very important to remove this gasket if you're not going to have ventilation holes cut. You don't want an airtight seal, because you don't want the enclosure to pressurize or potentially blow up.



Second, you'll notice there is no AC adapter in here to charge this. Most controllers do not need a solar panel source. You can plug any DC source into this. This controller has something like 10 or 20 profiles you can set up. I'm using just a standard laptop charger, I think 130 watts. I placed the XT60 connector on it, so I can plug it into the side XT60 port. You'll see the controller turn on and begin charging shortly. This controller will serve as both my AC charger and solar charger. I just have to remember when switching between sources to set the correct source on the charge controller. This can handle a maximum of 10 amps input and/or output, which is a good balance between not having to buy an expensive controller and having a separate component taking up more space and generating more heat.

Now the fun part — we're going to plug a few things in and see what it can do. First up is my cheap Black & Decker hammer drill, rated at 6.5 amps nominal. I'll just plug it in here. That's pretty cool — let's check the amps. That's a lot of amps.

The last thing I want to try is my Craftsman shop vac, rated at 7 amps. Slightly above the hammer drill, but in the same range. That was pulling about 19 amps when running, but it took a big spike on startup. We did the clamp meter test again — inrush was 70 amps from the battery at startup. That motor is sweet — actually incredible.

I'll run a few loads tonight to run down the battery a bit since it's fully charged. Hopefully tomorrow, we can take it outside and show solar charging. I have a 270-watt SunEdison panel. VMP (maximum power point voltage) is around 30.2 volts. I spliced the positive and negative leads onto an XT60 connector and plugged it in the charging port. Today is partly cloudy. Off that single panel, I'm getting about 180–185 watts of charge. This controller would have no problem handling two or three of these panels.