Tesla Battery for Solar Storage – Tips and Resources

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Introduction

This document summarises the key information that I found useful in setting up my own solar storage solution using a Tesla model 3 battery, and it would generally apply to other Tesla battery types and brands.

In my view, the use of a car battery for home solar storage is a good option. Advantages are that it has significantly more storage than traditional home storage options, it's much cheaper, the battery is ruggedised being designed to handle the treatment a car experiences, it can deliver more peak power than traditional home storage, and it involves reusing/repurposing. Cost wise for comparison, a Tesla Powerwall of 13.5kWh storage can discharge at 5kW continuous and costs about $12k (new). Whereas a Tesla battery is 50-60kWh of storage, can discharge many times more, and of similar cost to the Powerwall (noting a Tesla battery is second hand).

The main hurdle when using a car battery is that cars use a different communication protocol to inverters, so an emulator (interface) is required. While there are currently no "off the shelf" emulators available, there is sufficient information available online for a tech savvy person to make their own.

Please note this information is not a how-to guide, and is certainly not exhaustive. I hope that it is useful, but use it at your own risk and do your own research. Useful links are provided at the end of the document. And please do not skip the safety section!

Safety

WARNING: Tesla batteries operate at a dangerously high voltage, and are not to be messed with (especially since they are DC and can unload their power extremely quickly! This may cause sustained arcing, burns and fire). A Tesla battery can produce around 7,000 Amps if short circuited!

Furthermore, working at these voltages (e.g. 350 to 450 volts DC) is prescribed electrical work, meaning it must be done by a registered electrician.

It is highly likely that the battery fuse is blown and the Penthouse cover will need to be opened. The penthouse is the raised compartment on the battery that contains the pyro fuse, contactors etc. To do this safely, the correct personal protective equipment (PPE) is required. Note the Tesla fuse itself even contains a small explosive charge. When handling the inside of a Tesla battery, a good starting point for PPE would be high voltage gloves, face shield, protective clothing, and insulated tools.

It is a good idea to store the battery away from your house but protected from the weather. A separated garage or garden shed would seem appropriate, provided it is well ventilated with good ducting/cable management.

Overview

The three main components to a solar storage system are a battery, inverter, and an emulator (interface):

- Battery: Compatible with the emulator interface. In my case I used a Tesla Model 3 50kwh. Try to get the battery as "complete" as possible, unopened, and preferably with the HV (high voltage) orange cable.
- Inverter: Compatible with the emulator interface. In my case I used a GoodWe 20kWh (3 phase). Make sure you get a hybrid inverter that can run in backup mode, so that it can be used off-grid in the event of a power outage
- Emulator: I used a "Lilygo" mini computer device running code from "Dalathegreat" (see below link). This provides an interface between the battery and the inverter, translating the messages from each one and passing on the necessary information. It also does a degree of battery management and reporting.

For further information such as detailed guides and lists of compatible equipment, visit this website: https://github.com/dalathegreat/Battery-Emulator

There is plenty of useful information on this website. Even better, join his discord so you can unlock a wealth of knowledge and ask more experienced people questions.

The process generally will involve:

- Replacing the Pyrofuse in the battery
- Setting up the “Lilygo”, which requires installing and configuring free software
- Various electrical wiring including a 12v power source, a large capacitor across the main power cables, joining the HV aluminium cables to copper, and wiring up the X098 communications plug (8 wires)

Purchases

In addition to the solar battery and inverter, here is the list of items I purchased:

- Lilygo [about $20 from https://pt.aliexpress.com/item/1005003624034092.html]
- Pyro fuse [about $150 from jbhauto note this is a New Zealand supplier hence I chose them]
- X098 connector [about $10 from aliexpress]
- Socket for tesla screws to open the penthouse cover for fuse replacement [They’re called EPR10 / 8.8 /or google "secret Tesla five lobe socket", however I found a universal socket worked the best]
- Capacitor 500v 700uF [I bought from rsonline for about $35, however it’s good practice to get higher voltage capacitors than required so it would be better to get one rated at say 1,000v instead]

If you don’t have these already, you will also need:

- 12v lead-acid battery
- High Voltage orange cable to plug into the Tesla battery
- 60 Ohm resistor

Setting up the battery

The main objective is to get the “contactors” to close in the battery. These will liven the terminals and allow power to flow in and out.

Getting the contactors to close requires a working fuse in the battery, a 12v power source, a pre-charge capacitor, connecting the high voltage leads, completing the HVIL circuit, and the X098 wired up to the Lilygo for it to tell the battery to close the contactors. Each of these is discussed below:

Replace the Pyrofuse

The Pyrofuse is located inside penthouse cover. It blows if the car’s airbags go off, so it’s likely you’ll need to replace it. Whilst it is possible to bypass it (using a DC circuit breaker and 2 Ohm resistor across the monitoring pins) this is not recommended as the Pyro fuse self-monitors load and can trip on its own (even though the car central computer isn’t running) so it’s best to use a proper pyro fuse and retain the original safety functionality that it provides.

This is probably the most dangerous part of the process. Refer to the safety section and ensure you’re wearing PPE and take care not to short anything with your tools. I used a plastic case around the fuse so the screws didn’t drop or touch the side. Socket was either half-inch or 13mm.

After removing the fuse, always check the voltage potentials before putting in a new Pyrofuse. Check ground to each of the Pyrofuse connections, and also between them. Voltage between them is usually 100-180 volts but starts sagging slowly as soon as you connect the multi meter. It’s normal although a bit unintuitive. (The battery gets split into 2 halves when the pyro blows).

Lead Acid battery

A 12v power source is required via the two big pins on the battery. This power is used to close the contactors inside the battery. It requires a lot of power to do this (in the order of 30A, briefly) so make sure you have a decent lead-acid battery and sufficiently large cables going to the terminals.

It’s recommended to use a battery (e.g. Lead Acid or Li-ion) not a 12v transformer, so that you are able to startup the Tesla battery in the event of a power outage, if needed.

Once the contactors are closed, these two terminals on the battery then start sending out power, to keep the lead acid battery charged. Note this power supply runs up to 14v (because Tesla’s use a Li-ion battery for this) so it is recommended to drop the voltage slightly (I did it with a Diode) down to say 13v for the Lead Acid, otherwise long-term supplying 14v to a lead acid isn’t healthy for it.

Pre-charge capacitor

The battery runs a “pre charge” circuit before closing the contactors. This is done to avoid sending full power out to the drive unit instantaneously. Effectively the “pre charge” procedure involves ramping up the voltage from 0 to 350v in a relatively short space of time (approx. 1s). The battery needs to see a response from a capacitor charging otherwise it detects an issue and faults.

Therefore, it is necessary to install a capacitor to simulate a motor connected, in order to complete the pre-charge procedure and close the contactors.

The capacitor is installed directly across the main High Voltage cables. It can be done inside the penthouse but it’s preferable to do it outside the battery (to leave the battery unmodified) and inside an electrical box so that if the capacitor blows it doesn’t make a mess.

High Voltage Wiring

As noted before the high voltage DC wiring is classed as prescribed electrical work and therefore needs to be done by a registered electrician.

Draw power from the largest HV socket on the battery (the one with the large flat pins) using an orange HV lead. Alternatively you can connect to inside the penthouse (see photos on Dalathegreat website).

The Tesla cables from the high voltage plug are aluminium and will need to be joined to copper. Because of the different properties of aluminium and copper, correct joining links and technique should be used to avoid eventual failure of the joint.

You will need fuses or a DC rated circuit breaker close to the battery to protect your cable and inverter. Although there is the pyro fuse in the inverter, this is rated for something like 1000 Amps and won’t protect your copper cable which will be rated much lower than this.

The DC charging port (HV socket same side of the battery as the X098 socket) is not usable (it has its own contactors inside and is not live) but for safety it is recommended to cover this socket, a 3D printed template is available online.

Complete HVIL Circuit

One of the battery safety features is a “High Voltage Interlock” which is effectively checking that all the High Voltage (HV) cables are plugged in, using little pins in each of the HV sockets and making sure they’re all connected.

Satisfying the HVIL can be done by shorting the little central pins on all the HV plugs, plus adding a resistor (60-120ohm) across two pins in the X098 comms plug (covered elsewhere below).

In my case I was able to source the original HV cables, and these orange cable plugs have a little wire built into them that shorts the two little pins in the HV plug. So by plugging in each of the HV cables (2 in my case, there’s 3 on a 4 wheel drive model), plus the resister in the X098, I was able to get it to work without any custom made jumpers between the little pins in the HV sockets.

X098 Comms plug

Whilst it is possible to connect wires directly to the appropriate pins on the X098 socket, it is preferable to buy a connector and wire it properly.

The X098 comms connector needs 7 wires. Refer to the attached image for pin wiring:

- 2 wires for the HVIL resistor (just 60ohm resistor across them in my case)
- 2 wires for CAN communication which go to the Lilygo
- Then there’s 3 larger pins in the X098, 2 of them need 12v input into them plus 1 gnd/-ve.

I used a shielded Cat6 cable to connect these to the Lilygo and lead acid battery.

Wiring diagram

Refer to the attached wiring diagram.

I added a diode so the 12v lead acid doesn't feed the Tesla battery all the time, only when I press and hold the startup button (which is only required for a few seconds to get the contactors to close) then the 12v supply can be removed and the Tesla battery will stay active as it powers itself.

The way to disable the Tesla battery is to remove the 12v supply to the Battery Management System (BMS), i.e. remove the 12v feed to the X098 socket. Therefore I had another switch “BMS power supply” which allows me to disable the battery remotely if I want.

I wanted switches to control the power in my garage by the inverter (not in my garden shed with the Tesla battery), so I put the lead acid next to the Tesla battery and used relays to ensure there was good voltage at the battery (rather than running 12v from the lead acid all the way between the inverter and the Tesla battery). Note the 12v feed on the BMS and the 12v feed on the screw terminals to start the battery MUST be the same voltage for it to work.

Setting up the Lilygo

Follow the guide on the Dalathegreat github website linked below, but in short, the process involves:

- (optional) scratch off the terminating resistor (required if using a GoodWe inverter)
- Connect CAN wires to Inverter and BMS (if using GoodWe inverter they’re both wired into the CAN terminals)
- Provide a 5v power source (avoid using the 12v feed as it’s unstable)

Provisioning the LilyGo:

- Load Arduino IDE (free app) on to a computer and connect via USB to the Lilygo
- Download the software from the Dalathegreat github repository and compile it using the IDE (make sure you choose the correct inverter and battery settings before you compile it)
- Send to the Lilygo
- You can then monitor the Lilygo via the Arduino IDE while it is still connected to USB to check any errors from the Battery. After disconnected, if you have enabled it, you can monitor status via wifi webpage

Setting up the Inverter

When specifying settings in the inverter, set the battery type to BYD HVM (this is the battery type the LilyGo will emulate), note there can be multiple BYD options so check the website links below for details.

In my case I also had to get a technician to adjust the battery voltage safety limit in the inverter from 360v up to 400v otherwise it stops charging (seeing as it’s not actually a BYD battery so the voltages were slightly different).

Useful links

Hardware links are included in the section above under purchases.

Below are the main links I found useful in setting up the system:

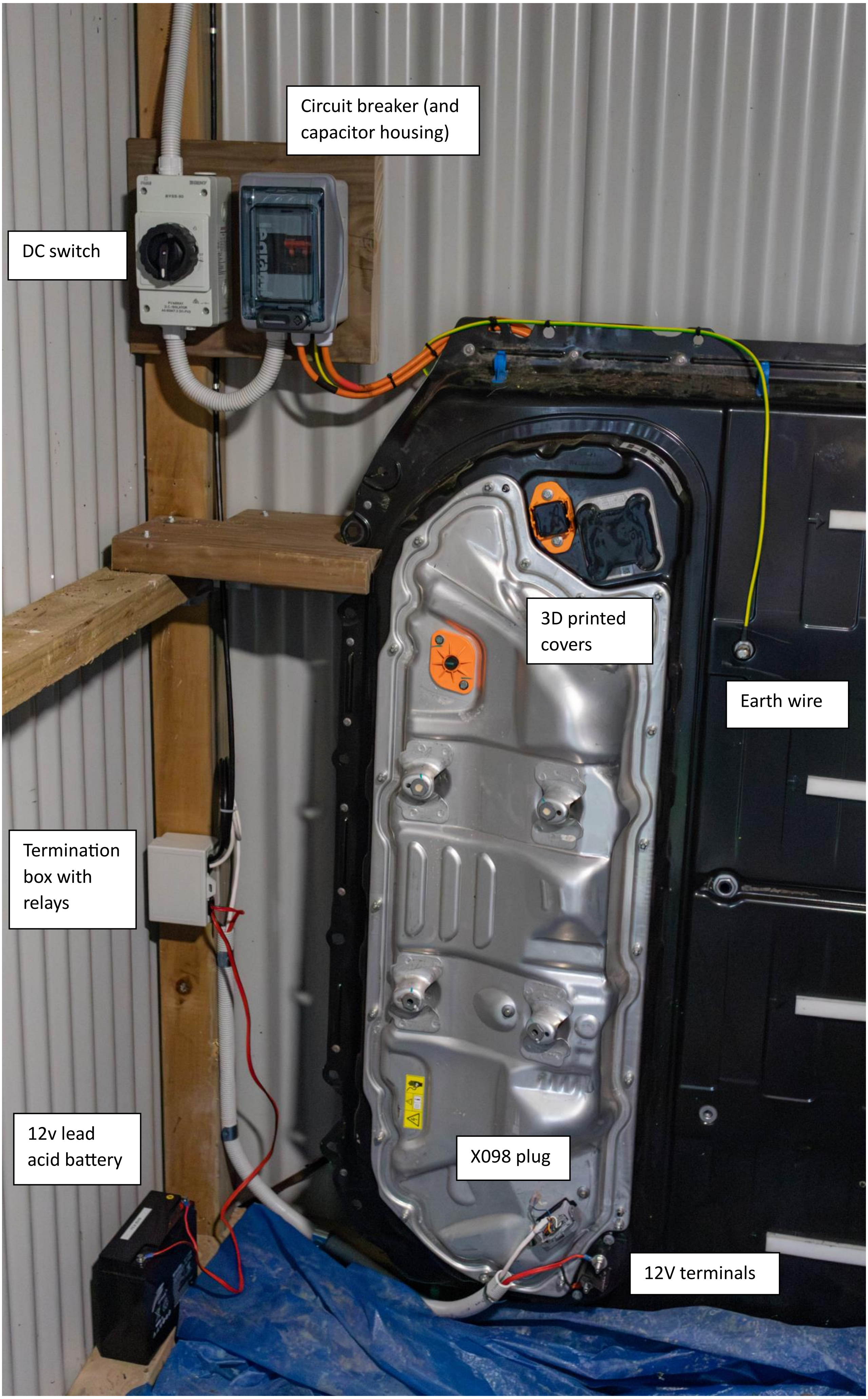
- Main Dalathegreat website (to use their Lilygo firmware) https://github.com/dalathegreat/Battery-Emulator
- Tesla specific info https://github.com/dalathegreat/Battery-Emulator/wiki/Tesla-Model-S-3-X-Y-battery
- GoodWe specific info https://github.com/dalathegreat/Battery-Emulator/wiki/Goodwe-inverters

Here are some other potentially useful links:

- Alterative wiring diagram in folder from forum, and lots of forum discussion: https://openinverter.org/forum/viewtopic.php?t=1650&start=125
- Open wiki page https://openinverter.org/wiki/Tesla_Model_3_Battery
- Someones good summary with photos https://mbolt.notion.site/Tesla-M3-battery-59772a8a9dd349509c83a2953b88387c#fa1995290ab34519b1fc694bbe4a114a

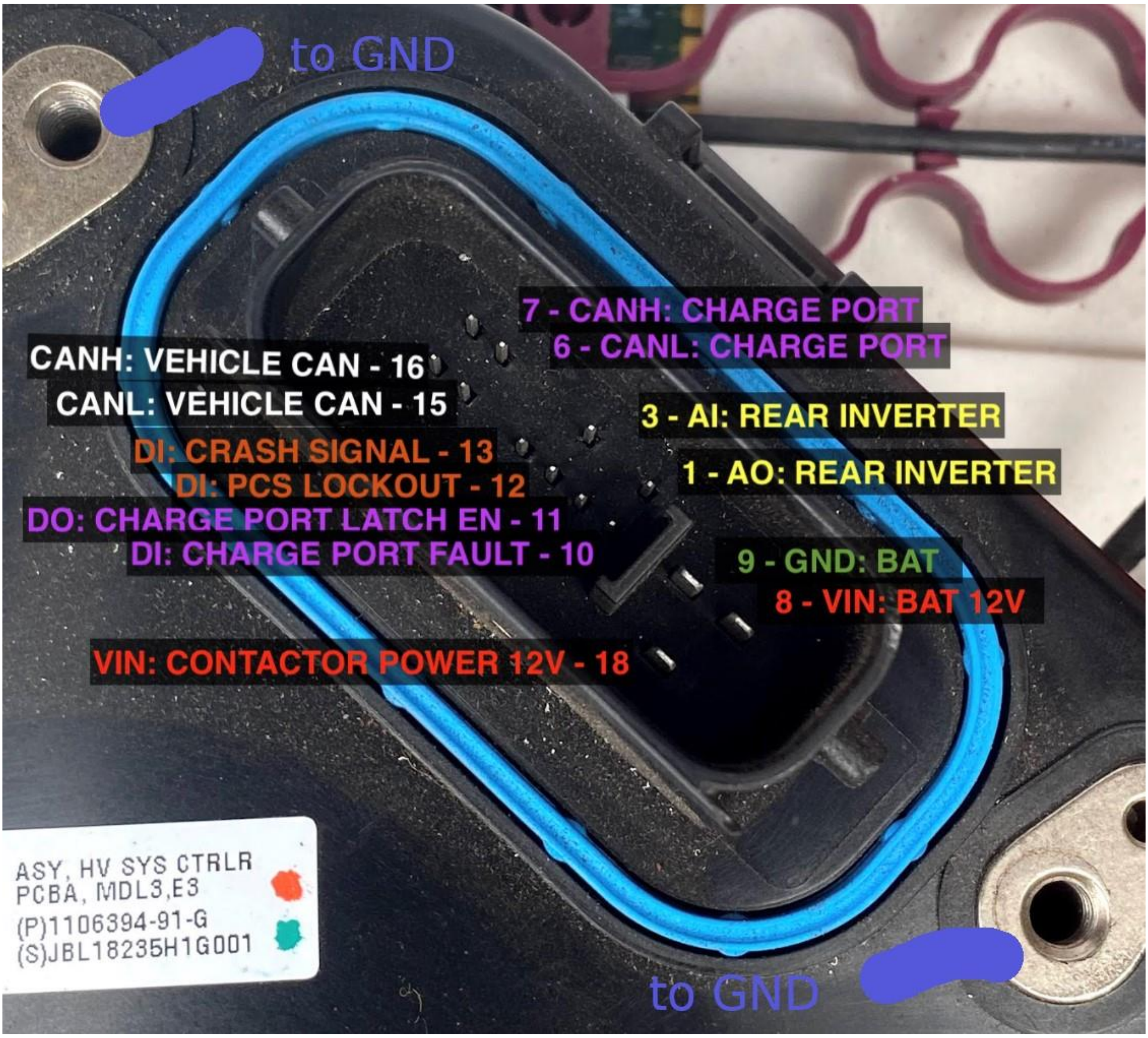
Attachments:

- Photos: Two photos attached of my completed system.
- X098 pin numbering
- Circuit diagram: Showing how I’ve wired my system.



Circuit breaker (and capacitor housing)
DC switch
3D printed covers
Earth wire
Termination box with relays
12v lead acid battery
X098 plug
12V terminals


Lilygo and power supply switches
PV ARRAY D.C. ISOLATOR
PV STRINGS 1+2 NORTH FACING
PV ARRAY D.C. ISOLATOR
PV STRING 3 WEST FACING

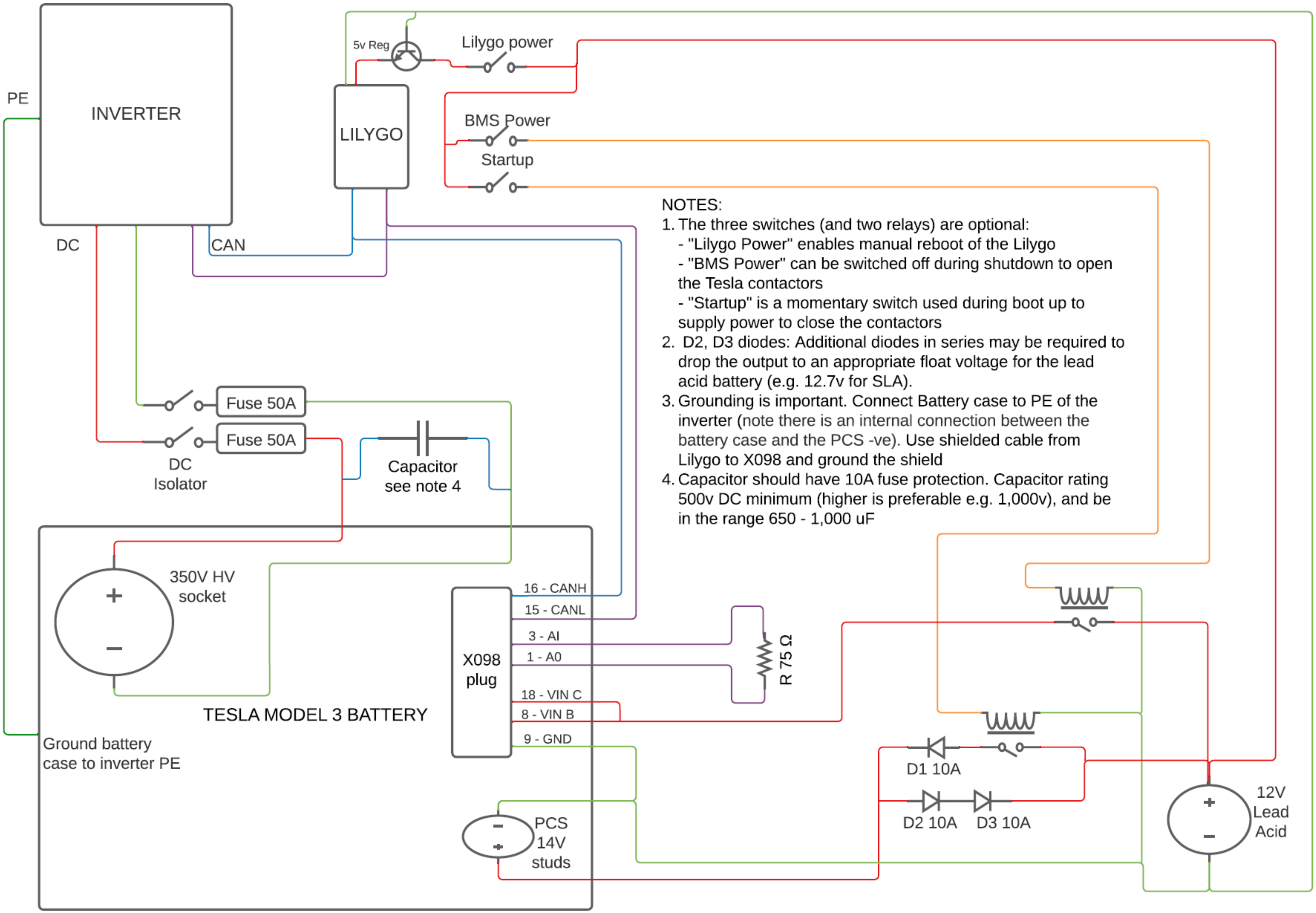


X098 Connector (source: Dalathegreat)

NOTE: There are only 7 wires needed, which are:

- Red (12v)
- Green (Gnd)
- Yellow (60 Ohm resistor across these)
- White (CAN communication to Lilygo)

Additionally, the side screws need to be grounded IF the X098 is removed from the Battery. In my case I kept the whole battery and X098 socket intact so I did not need to connect these to ground.



NOTES:

1. The three switches (and two relays) are optional:
   - "Lilygo Power" enables manual reboot of the Lilygo
   - "BMS Power" can be switched off during shutdown to open the Tesla contactors
   - "Startup" is a momentary switch used during boot up to supply power to close the contactors
2. D2, D3 diodes: Additional diodes in series may be required to drop the output to an appropriate float voltage for the lead acid battery (e.g. 12.7v for SLA).
3. Grounding is important. Connect Battery case to PE of the inverter (note there is an internal connection between the battery case and the PCS -ve). Use shielded cable from Lilygo to X098 and ground the shield
4. Capacitor should have 10A fuse protection. Capacitor rating 500v DC minimum (higher is preferable e.g. 1,000v), and be in the range 650 - 1,000 uF