EMW JuiceBox – an Open Source 15kW 60A Level 2 EVSE

V8.3-V8.6 Build Instructions

Updated: October 13, 2013

The latest full version of this assembly manual is always available from http://www.emotorwerks.com/JuiceBox_Public/8.3/ (Assembly Manuals folder). Note that V8.6 boards' instructions are covered in this manual, as well. There are just 2-3 differences and they are clearly highlighted in text below.

Message from the Founder

Dear Fellow EV Enthusiast!

Congratulations on purchasing the 15kW 60A Open Source JuiceBox Kit!

By assembling this device yourself, you will better understand how the modern EV charging systems work and will enjoy your EV much more – knowing that you have built part of your charging 'infrastructure' yourself.

You will also learn a good bit about open-source microcontroller hardware - the exciting revolution that is happening in the hardware world today. By moving power to make things from big corporations to people like you, we all will innovate faster and make things better faster for all to enjoy!

Finally, you will be able to easily adapt the JuiceBox to your liking – all the designs are completely open source and the latest versions are always available from Electric Motor Werks. Contact us anytime at JB-support@emotorwerks.com if you have any questions.

Thank you again for joining us on this journey to more sustainable and fun transportation!

A special thank you goes to all our KickStarter backers! Without you, this product would not exist. If you are not our KickStarter backer, check out our original KS campaign at http://www.kickstarter.com/projects/emw/emw-juicebox-an-open-source-level-2-ev-charging-st - it has a lot of good info on the product, our philosophy and what we are trying to do.

EMW JuiceBox is not just another EVSE – it's a completely flexible EV charging platform.

Go Electric!
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Valery Miftakhov, Founder, Electric Motor Werks, Inc. – on behalf of our great Team!

CAUTION!

This is a High-Voltage, High-Power design.

It is NOT your average weekend electronics project so do NOT treat it like one.

If not approached with caution and extreme attention to detail, this project can kill you, burn your house, etc.

By starting this project, you expressly agree that neither EMW nor any of its directors, employees, or partners are liable for any damage that may result from this project and associated activities.

Furthermore, there is no explicit or implicit warranty or guarantee of applicability for any particular purpose. For JuiceBox Kits, EMW will only warranty the parts to be free from manufacturing defects for 1 (one) year from the date of purchase. For the assembled units, EMW will warranty the parts and complete assembly to be free from manufacturing defects for 1 (one) year from the date of purchase.

What am I building?

EMW JuiceBox is an Open Source 15kW Level 2 EV charging station costing 10x lower than currently existing EVSEs of similar power.

This product was initially successfully funded from a KickStarter campaign. The project received over 230% of the target funding amount from around 300 backers.

The device is a full-featured J1772 charging station and supplies up to 60A 15kW to your J1772 vehicle (all production cars sold today) and operates on any voltage between 100V and 240V. This means up to 10x faster charging than from a regular household outlet (when wired to 240V supply, subject to charging speed limitations of the charger onboard of your EV). Generally, most of the newer EVs will experience at least 4-5x improvement by going to 240v with JuiceBox.

It's built around an Arduino microcontroller and EMW is making both the hardware and software open source. It is small enough to be used as a mobile charger (plug in at the RV park, friend's house's dryer outlet, etc). It is faster. It is Wi-Fi ready. It is more affordable and flexible than other EVSEs available on the market today.

It is also completely open source. We expect many extensions to be made available in the future - developed by EMW or our JuiceBox developer community.You will be able to get the benefit of the great open source community around this product and get much more mileage out of your investment.

Finally, the JuiceBox is designed to be inherently portable. The Base version's dimensions allow you to take it everywhere and enjoy up to 15kW of charging power. There is an automatic power derating for 120V outlets so you don't have to worry about overloading your house wiring in that unfortunate event when you have to resort to 120V charging.

There are FOUR main configurations of the JuiceBox - Base Kit, Base Assembled, Premium Kit, and Premium Assembled.

Base Edition - DIY Kit

Includes all electronic components and matching enclosure needed to enable J1772 charging of your vehicle up to 240V 60A (output current limit is user-adjustable). No LCD screen or advanced controls.

Size: portable with ~10x7x3" weather-resistant enclosure. The cables are exiting from the bottom of the enclosure (from one of the small 7x3" sizes) so you will need some space below the JuiceBox to allow for cable routing.

You will need to add input and output cables - e.g., a dryer plug with cord for input and J1772 cord for output - a variety of options are available through EMW store - check related products. Or you can reuse the J1772 charging cord that you got with your EV.

Basic electronics assembly and safety skills required. Estimated assembly time is 1-2 hours

Base Edition - Assembled

Same functionality as our Base Kits but fully assembled & ready to go. Just add input and output cables (check related products in our store for more information for cable details. Or you can reuse the 120V charging cord that you got with your EV. If you buy cables from us before your JuiceBox ships, we will connect them to your JuiceBox for free).

Premium Edition - DIY Kit

Same functionality as our Base Kits PLUS:

(1) Color LCD Screen with charging info, total $ saved by driving electric, total energy consumed, etc.
(2) Time of Day charging control - save money by charging at night without having to remember to plug in at midnight
(3) Full GFCI protection comes standard - recommended for outdoor & permanent installations
(4) Larger, very cool-looking, unique enclosure custom-designed for EMW JuiceBox - with provisions for LCD screen, USB programming connection, etc.
(5) Remote control via a secure keyfob

The kits will require just basic electronics safety and assembly / soldering skills and can be assembled in 3-4 hours.

Size: the enclosure is a 5-5.5" diameter cylinder, 16-17" in height (as of September 16th, the final dimensions are being finalized). The cables are exiting from the bottom of the cylinder so you will need some space below the JuiceBox to allow for cable routing.

Premium Edition - Assembled

Same functionality as our Premium Kits but fully assembled & ready to go. Just add input and output cables (see related products in our store for cable details; if you buy cables from us before your JuiceBox ships, we will connect them to your JuiceBox for free)

Specifications and Features

- Specifications:
  - Input voltage: 100-265V
  - Output power: 15kW / 60A
    - Whichever is smaller (i.e. at 208V supply, the JuiceBox allows 208*60 ~ 12.5kW)
    - Automatic power derating for 120V use – no need to reset the power limit when changing between 120V and 240V
  - Output type: J1772
  - Size: 11x7x3” (Base), 17x5.5x5.5 (Premium)
  - Environmental protection level: waterproof up to IP66 (when properly assembled and mounted)
  - Operating conditions
    - Outside temperature: -20C – 65C
    - Humidity: up to 100%
- Features:
  - Multiple protection levels
    - GFCI (Ground Fault Circuit Interrupter) – ~20mA trip point – protect from electric shock
    - Standard J1772 power interlock – the output is not energized unless connected to a properly configured J1772 vehicle
    - Stuck relay protection – charging is disabled if internal relay is stuck closed
  - Variable output current limit – set via an internal variable resistor (Base) and / or via an LCD interface (Premium)
  - LCD interface for display of major parameters (user adjustable through firmware)
  - Remote control (premium edition) via a secure KeyFob with 4 buttons
  - Full hardware and software expansion potential
    - Open source hardware and software design
    - Hardware expansion through Arduino shields (UNO footprint provided)
  - Wi-FI ready
    - Firmware and hardware fully ready for an addition of the Wi-FI expansion shield (based on a Roving Networks RN171-XV WiFi module)
    - Server-side application is being developed to allow JuiceBox owners to monitor their JuiceBoxes via internet
    - Automatic WPS-based WIFI configuration with a single button press
    - Note: a purchase of an EMW WiFI shield is required to enable WiFI functionality

Release notes for V8.3

You MAY receive a partially or completely assembled board. In this case, please go through the instructions below and identify parts that are not installed. Follow instructions to place them

You MAY receive an incomplete KIT. As mentioned in our KickStarter update #16 (linked from our main KickStarter project page at http://www.kickstarter.com/projects/emw/emw-juicebox-an-open-source-level-2-ev-charging-st), we have decided to start shipping electronic part of the kit before the cables – this will allow you to get started on assembly / software testing while we are waiting for shipments of the remaining large parts to come from China. A container ship takes up to a month to cross the ocean so we understandably have some delays.

Build support

Just like with our other products (see http://emotorwerks.com/tech/electronics for example), we are committed to getting our customers to the finish line on their builds! We have never abandoned a single customer and some of our build assistance threads run into hundreds of emails on our most complex products!

That said, we CANNOT offer phone support for any consumer purchases. This is how we are able to maintain our low prices – phone support is EXTREMELY expensive and INEFFICIENT. It is a well-known fact that email resolution of a problem costs less than 20% of the cost of resolving the same problem over the phone. A lot of times, it is also faster to resolve things over email. Finally, in email, there is always a record of what's happening – which is always very useful for debugging issues.

As a summary, only email support will be available. Email all JuiceBox questions to JB-support@emotorwerks.com

Finally, please understand that we assume that if you bought a KIT and not a fully assembled product, you know what you are doing. If you have never soldered anything before, it's a BAD IDEA to buy a kit like this – see our CAUTION page for details.

Part 0. Before you start

1. **Required tools:**
    1. Soldering setup
        a. A low-power soldering station with a relatively fine element
            i. 20W MINIMUM, 40W MAXIMUM or adjustable
            ii. Something like this (what we use at EMW, $20 from Amazon)
        b. Electrical solder
            i. Make sure you never use a plumbing solder as it may have conductive flux!
            ii. Ideally 0.3-0.5mm thick
        c. If you haven't done much soldering before, check http://www.dummies.com/how-to/content/what-is-soldering-and-how-do-you-use-solder-tools.html
        d. Some quick tips
            i. Heat the lead, not solder – feed solder into the joint and let it melt & cover the entire joint before you remove the iron
            ii. Especially follow this for ground plane connections – where the pin connects to wide copper areas – they tend to dissipate heat very quickly and you will have to hold your iron on them up to 2x longer
    2. Screwdrivers
    3. Wire stripper & crimper
    4. Small snips for wire / lead cutting
    5. Small pliers
    6. Clear Protective Goggles
    7. FTDI cable (something like https://www.sparkfun.com/products/9716
        a. **For limited time, we will be including these in kit shipments as a token of recognition to our supporters!**)

2. **Strongly recommended tools**
    1. Multi-meter with Capacitance / Resistance measurements – something like this ($20 on Amazon):
        a. Also download / print the resistor color coding reference: http://en.wikipedia.org/wiki/Electronic_color_code
    2. Clamp meter with 100A+ AC current measurement capacity (something like this – $40 on Amazon)
    3. Infrared thermometer such as this ($40 on Amazon)
    4. Scope with at least 1MHz bandwidth. You can get one of these small units – they are open source and generally don't have huge bandwidths / feature sets but will do the job just fine. In fact, we love these due to their portability – you can take this battery-powered unit anywhere!

3. **Helpful aids**
    1. Flat piece of thin plastic / carton to hold the parts while you turn over the board

to solder so that components don't fall out

2. Small soldering vise to hold PCB while you solder
3. Magnifying glass to read small parts' markings

4. Assembly Tips

1. Sequence of assembly is often quite important: some parts may not be able to fit after others have been soldered – be especially careful in the areas where parts are placed from both sides of the board
2. Read instructions for the ENTIRE step before proceeding with the first instruction under that step. Ideally, you should scan this entire doc before starting assembly
3. Place many parts at a time, bending pins on the other side of the board so that the parts stay in place when you turn over the board to solder
4. To prevent circuit shorts, make sure all unnecessary solder is cleaned from board.
5. Do not overheat the SMD parts – short leads make them prone to overheating

5. Education

1. Wouldn't it be nice to actually understand what you are building?
2. You can pick up quite a bit by looking at a few good references
    a. http://en.wikipedia.org/wiki/SAE_J1772
    b. http://code.google.com/p/open-evse/wiki/J1772Basics

Part 1. Project description

Assuming you have all the tools available, and have good experience in electronic assembly, you should allow 1 hour for PCB assembly, 1 hour for component mounting and wiring, and ~1 hour for testing of the Base version and 2x that for the Premium version.

This does not include the time required to make any adjustments you might need to make to your house's electrical system to provide adequate / desired AC power to JuiceBox.

To provide AC power to the JuiceBox, we recommend you to have a standard 14-50R RV outlet installed near the location where you are planning to mount your JuiceBox. You could also plug the JuiceBox into the 30A dryer outlets but the power will be limited to the outlet rating (note that you still have to set the power limitation on the JuiceBox – it will NOT automatically sense the power capability of your circuit – all 240V sources will look the same to the internal circuitry).

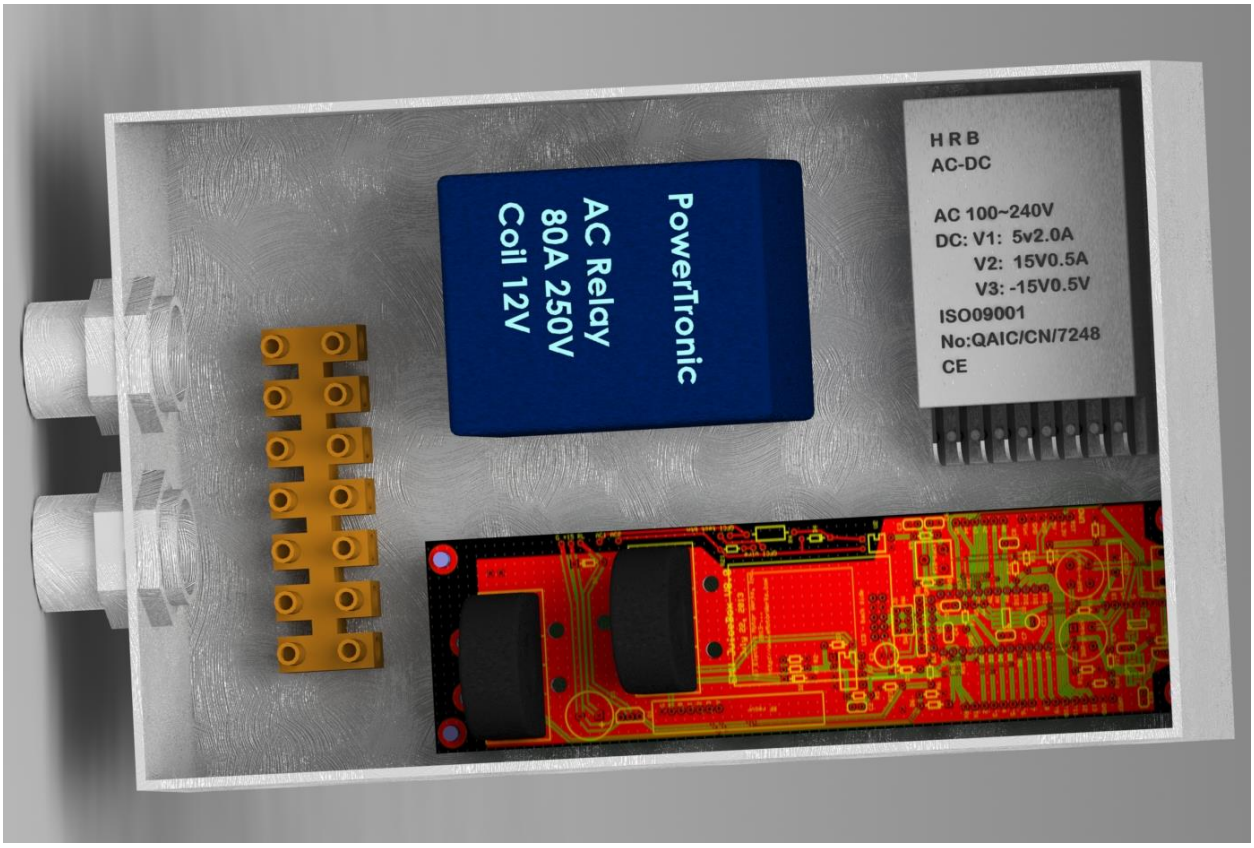
Some stats:

1. Total electronic parts count: ~50 for Base version, 55 for Premium version
2. Total unique electronic part count: ~30 for Base, ~50 for Premium
3. Total other electric parts: ~20 (e.g., relay, power supply, wiring, etc)

Overall build reference:

Use the image below to get a general idea of relative placement of components (Base Edition shown). Specific details are described in the corresponding sections of this document.


CS2
AC1050, AC1060,
AC1075 – GFCI


PowerTronic
AC Relay
80A 250V
Coil 12V
H R B
AC-DC
AC 100~240V
DC: V1: 5v2.0A
V2: 15V0.5A
V3: -15V0.5V
ISO09001
No:QAIC/CN/7248
CE


EMW JuiceBox
Base Edition
Level 2 EV Charging Station
Output Power: 15kW
Output Current: 60A
Input: 120V-240V
www.eMotorWerks.com

Part 2. Kit Contents

Please refer to the Bill Of Materials file on our site for more details on component lists, part numbers, etc: http://www.emotorwerks.com/JuiceBox_Public/8.3/.

Tip: enter part number into the DigiKey (http://www.DigiKey.com) search box to get a detailed part info page with full datasheets, photos, etc.

We are still working out what the best way is to organize the kits. Some of you will receive parts taped to a piece of paper with part names, some of you will get parts separated in a few anti-static bags, etc.

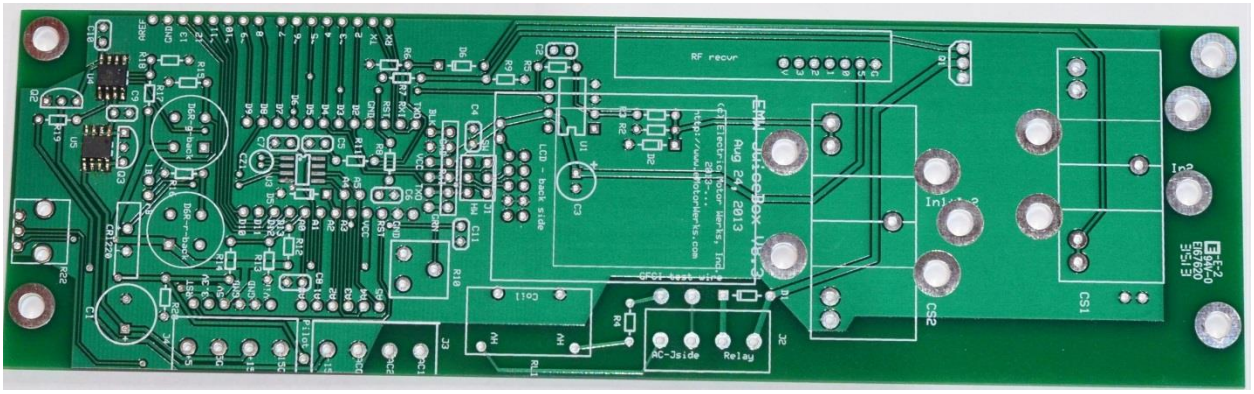
Majority of the parts will have clear manufacturer labeling on them, except resistors. You MAY have to use a color-code aid to decipher the resistor values (see required tools section above for links to all such aids)

Update (October 1st, 2013): many of you may be receiving fully assembled boards. We are trying to get these to as many kit customers as possible but may not be able to get to all of you. Please remember that the original description of the kit explicitly mentioned assembly of the PCB from components.

Base Edition kit V8.3:

Part 3. Assemble the main PCB

The matching PCB file is always in the PCB layout section of the corresponding JuiceBox version on our site - : http://www.emotorwerks.com/JuiceBox_Public/8.3/.

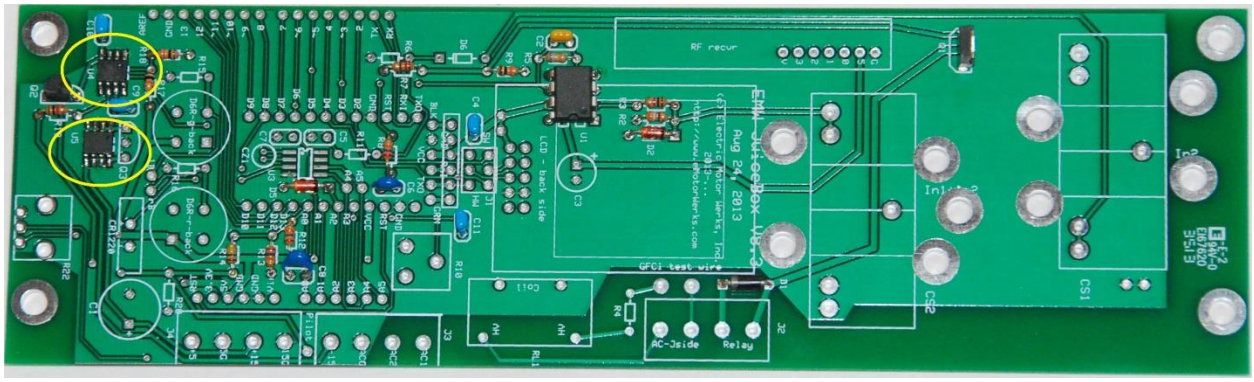


This is how the PCB will look when you receive it.

Note: there WILL ALWAYS be some part outlines on the board that are NOT filled in – we are using universal boards that fit many variations of the product. This allows us to lower your prices quite dramatically. Please do not panic if you 'don't have all the parts' – follow the instructions, identify the parts you really need, find them in your kit and if you still believe you're missing parts, then contact us.

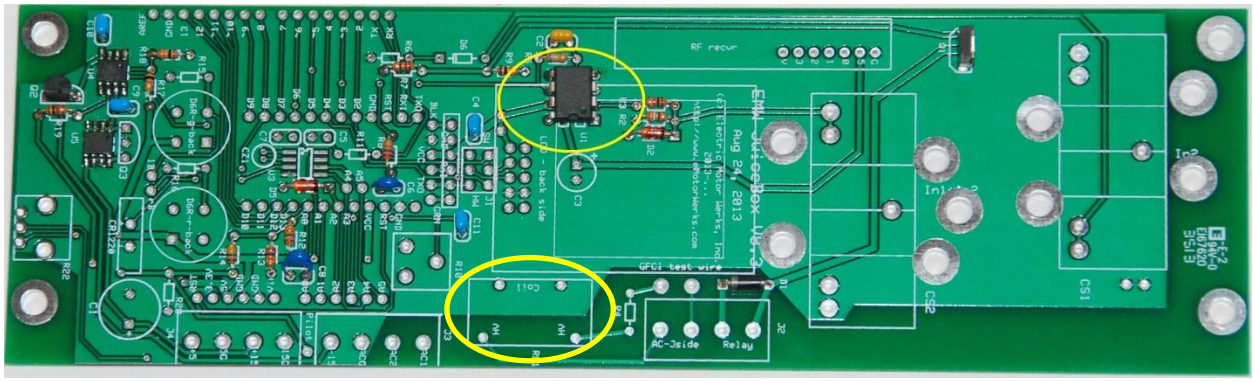
1. **Base Edition Sequence** (GFCI components marked with a * - optional for the non-GFCI version)**:**

   a. Group 1: SMD components



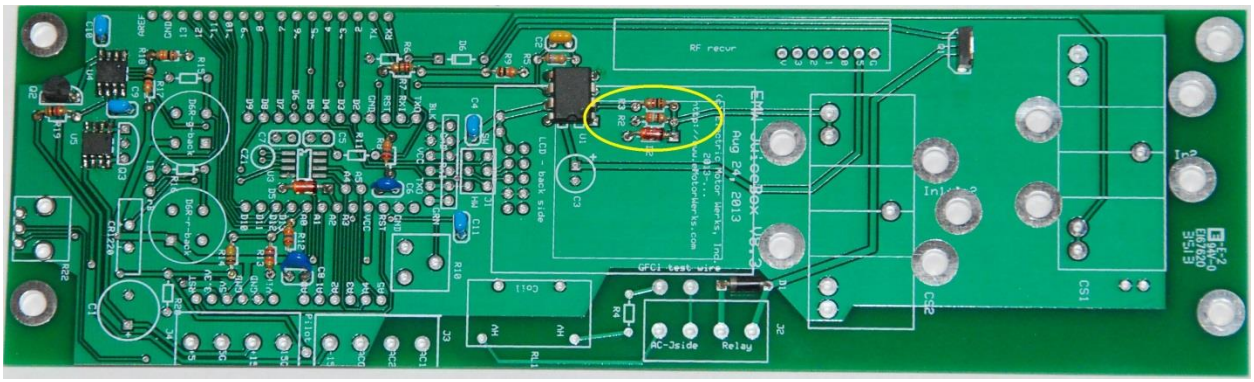
   a. Place Output Op Amp (SOIC-8 package, part ID LM7321MA): U4 – ENSURE CORRECT ORIENTATION – the dot on the package marks pin 1. Solder
   b. Place +12 Precision LDO (SOIC-8 package, part ID J25A3 or similar – black on black – we know it's not a convenient color scheme but that's not our fault…): U5 – ENSURE CORRECT ORIENTATION – dot=pin 1. Solder

b. Group 2: ICs

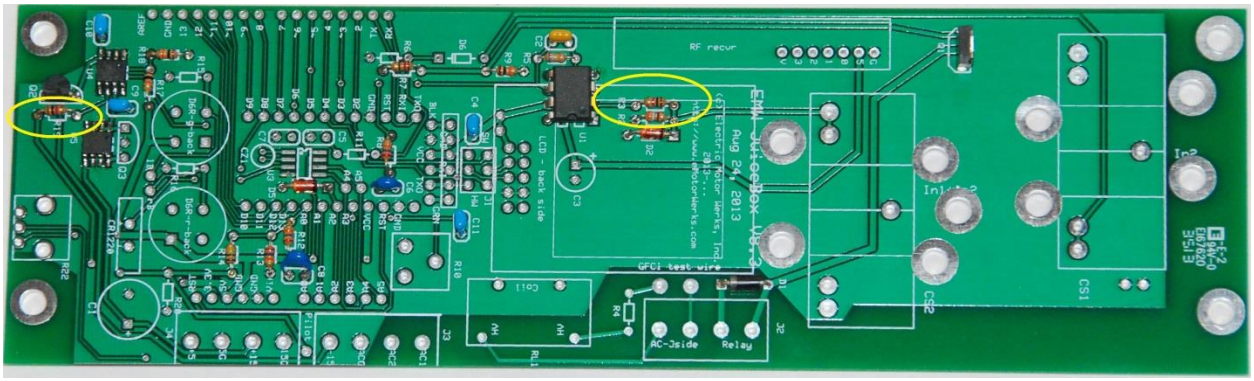


a. Place MCP601: U1*
b. Place 500ma Relay RL1
c. Turn PCB over, Solder components

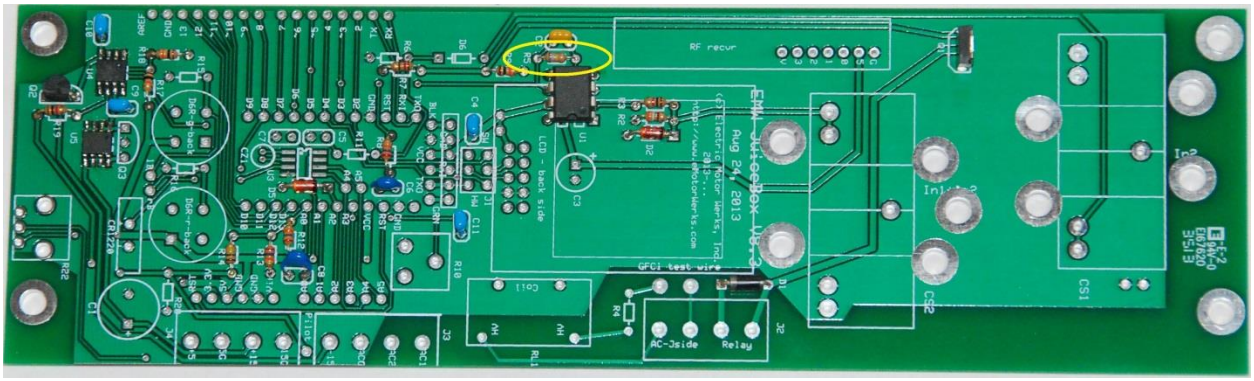
c. Group 3: Resistors, Small capacitors, etc.
   i. Resistors
      a. Place 390 ohm: R2*



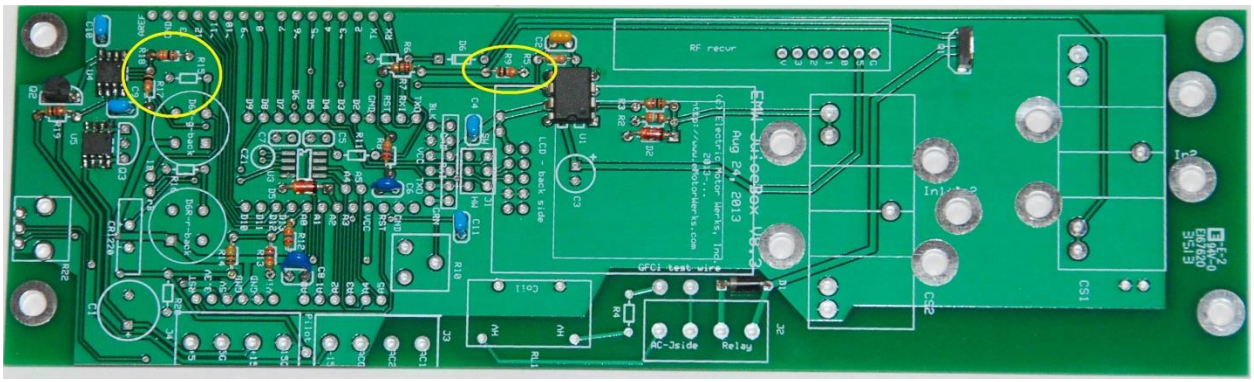
b. Place 1k: R3*, R19



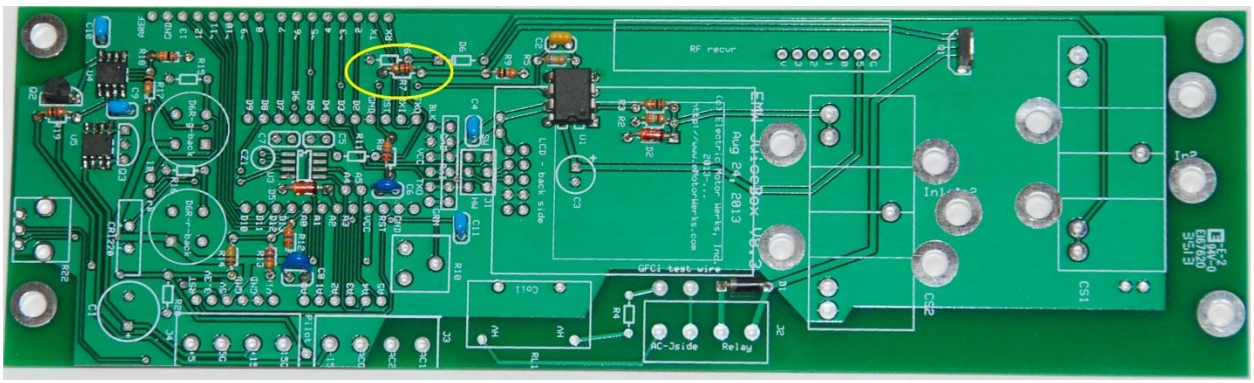
c. Place 680k: R5*



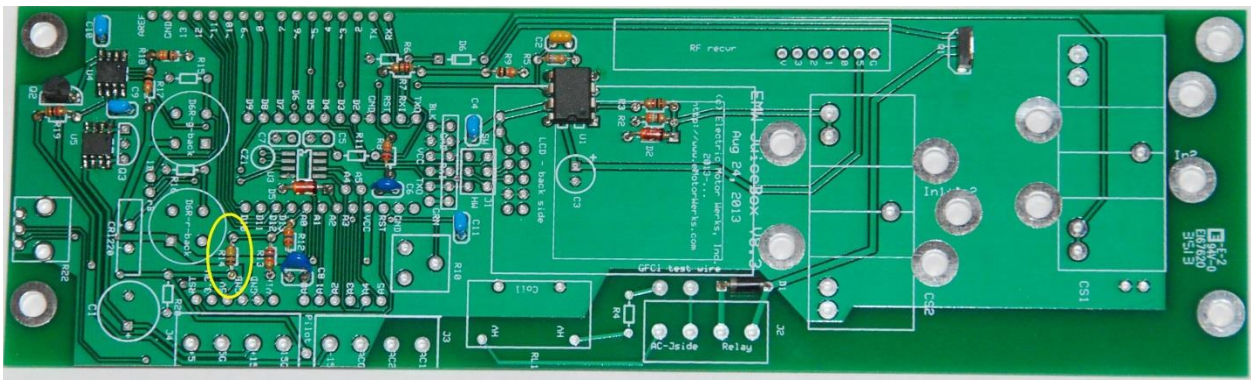
d. Place 10k 1/8W: R17, R18, R9



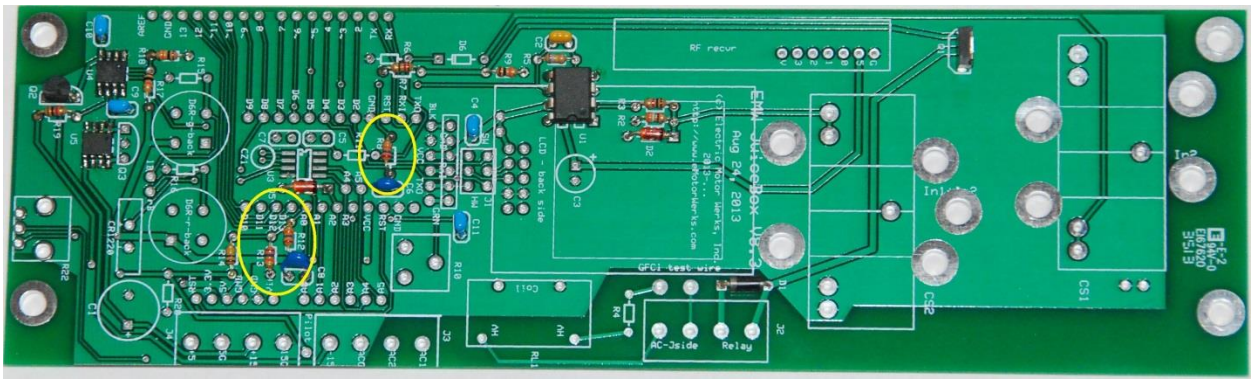
e. Place 120R: R7



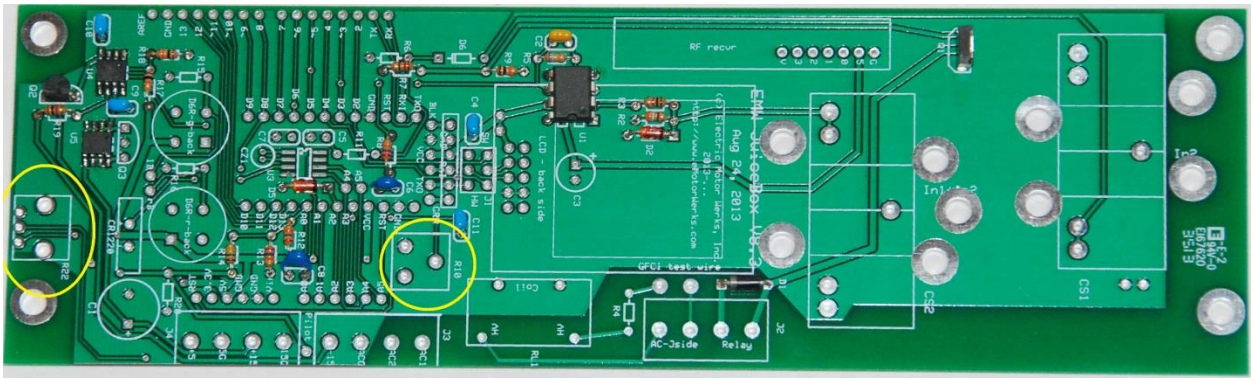
f. Place 100k: R14



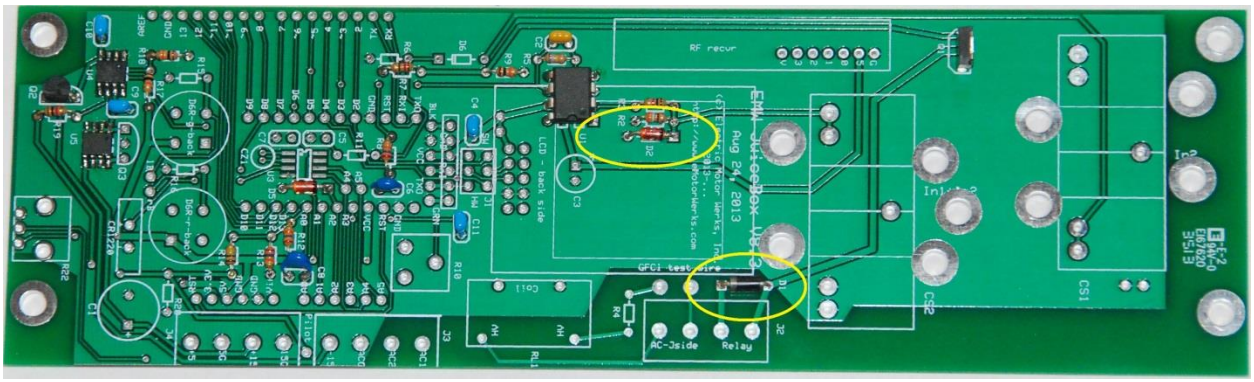
g. Place 27k: R8*, R12, R13



h. Place output current setting trimpot: R10
    i. If the external control of the output current limit is required / desired, you can also install R22 instead of R10 (right-angle trimpot, designed to be sticking out of the enclosure when installed – not included in the default kits)
    ii. Note that if R22 is installed and is protruding through the enclosure, the JuiceBox will no longer be waterproof or weather-resistant

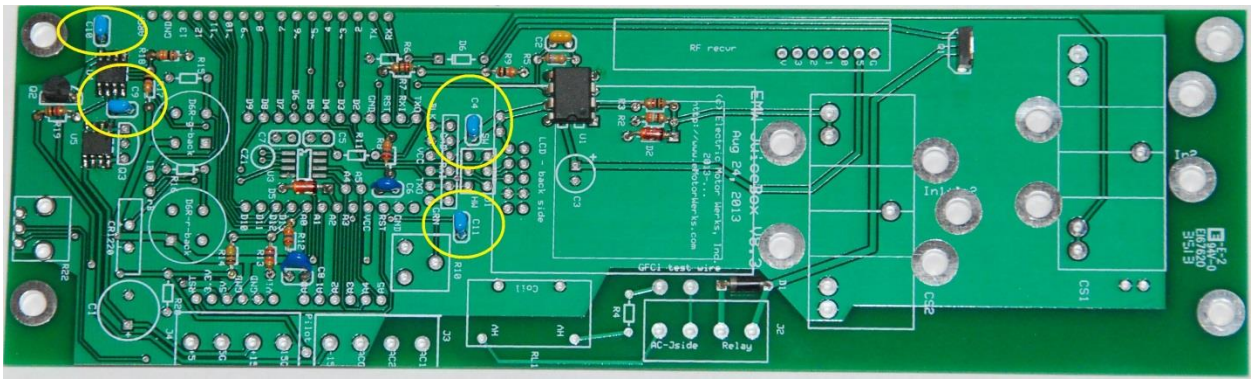


ii. Diodes
    a. Place Fast Diode 1N4934: D1
    b. Place 3.3v zener diode: D2*

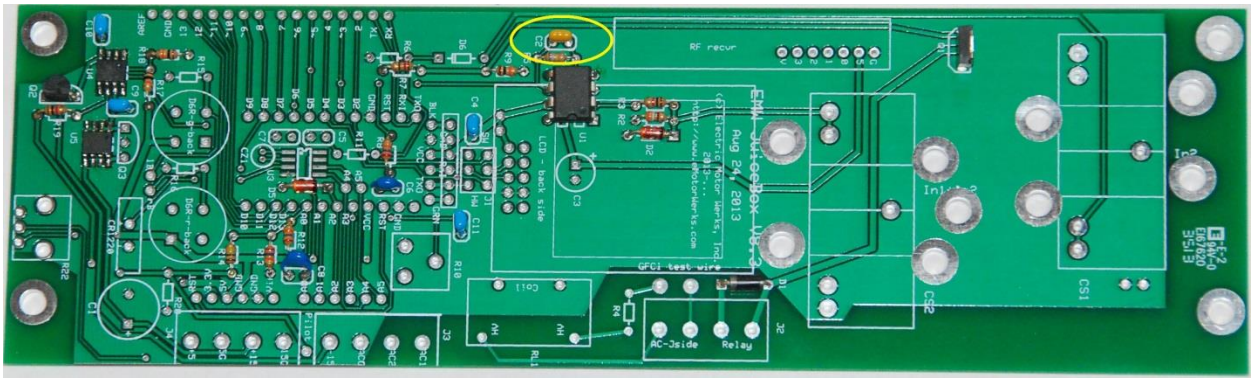


iii. Capacitors

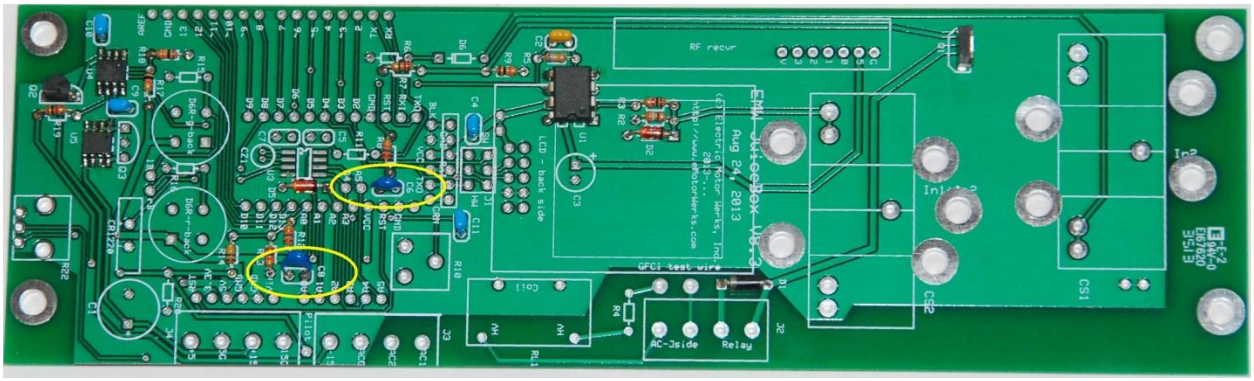
a. Place 0.1uF (104) cap: C4, C9, C10, C11



b. Place 330pf cap: C2*

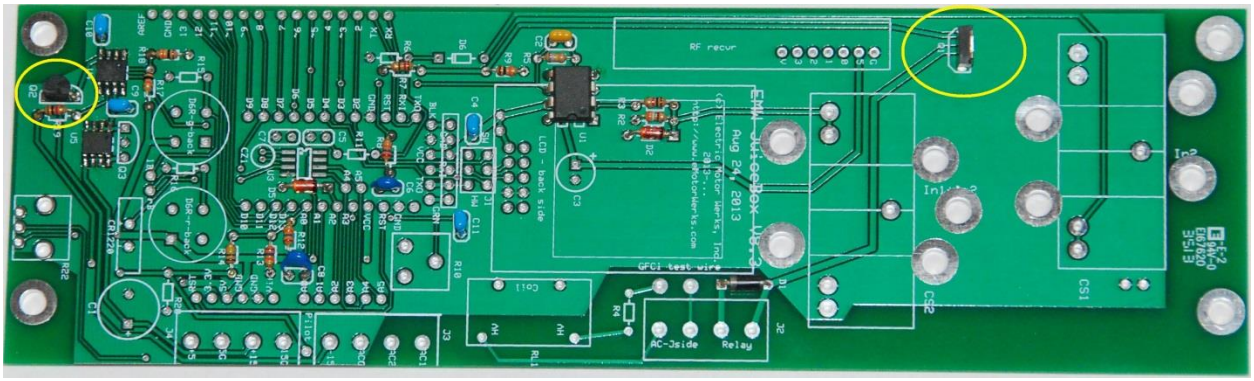


c. Place 3.3uF (335) cap: C6*, C8



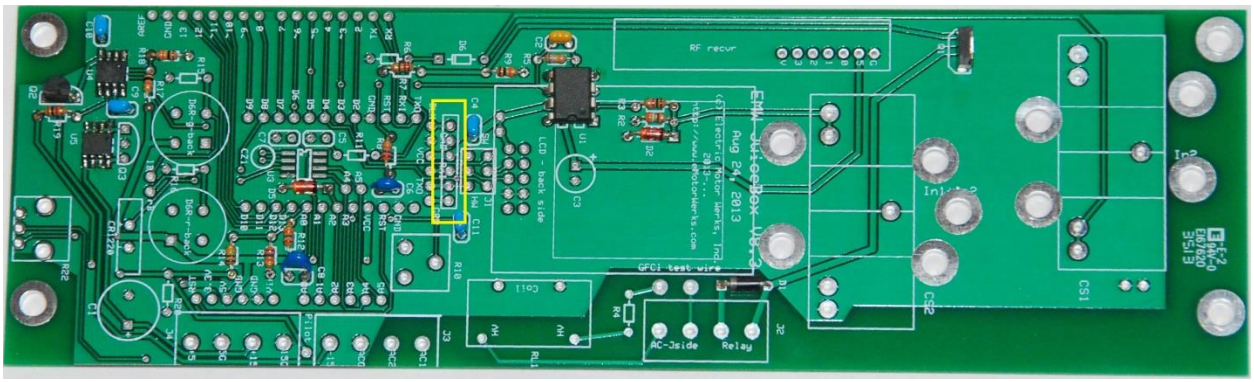
iv. Other semiconductors

a. Place -12V LDO regulator (TO-92 3-pin package): Q2
b. Place 30V 6.9A N-channel FET (NTD4815N-35G): Q1



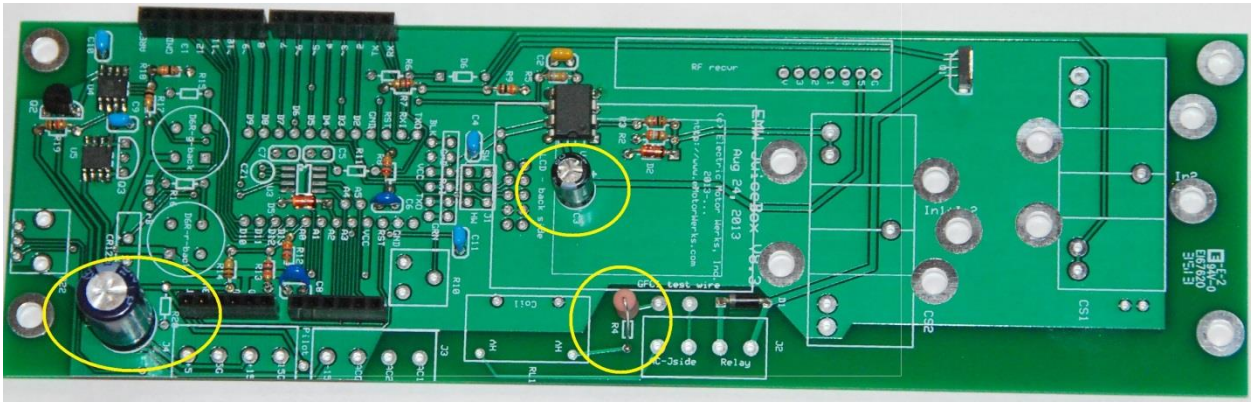
v. Turn PCB over, Solder components, cut the leads.

d. Group 4: Pins and Sockets
   i. Place 0.1”-pitch 1x 6-pin male pin header (Arduino programming header)

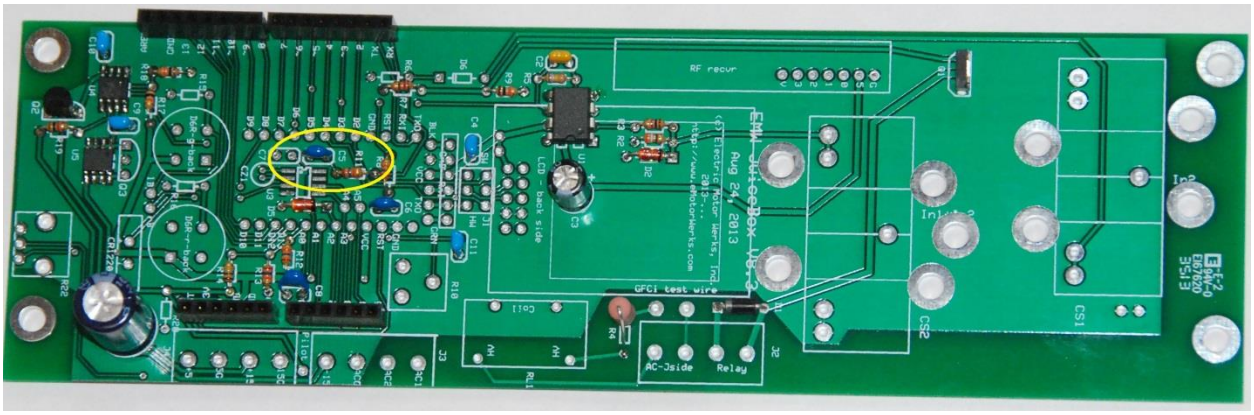


   ii. If desired, place 2x 8-pin and 2x 6-pin female headers along the sides of the board on the left for shield mounts
   iii. Place flat object over top of the board to hold everything in place and turn PCB over, solder pins

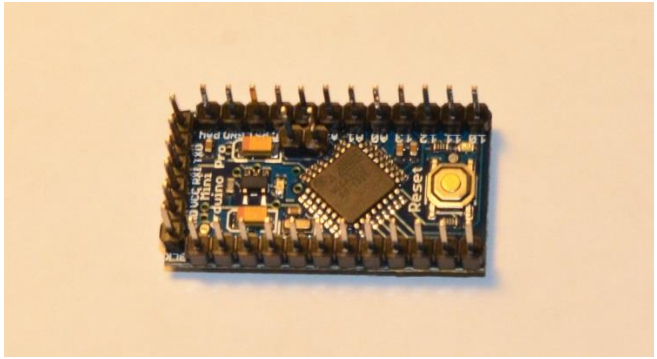
e. Group 5: Larger Top Board components
   i. Place 47uF 16V (or higher) capacitor: C3
   ii. Place 330-1000uF 25V (or higher) capacitor: C1
   iii. Place 10k 2W: R4*
   iv. Turn PCB over, solder, cut leads.



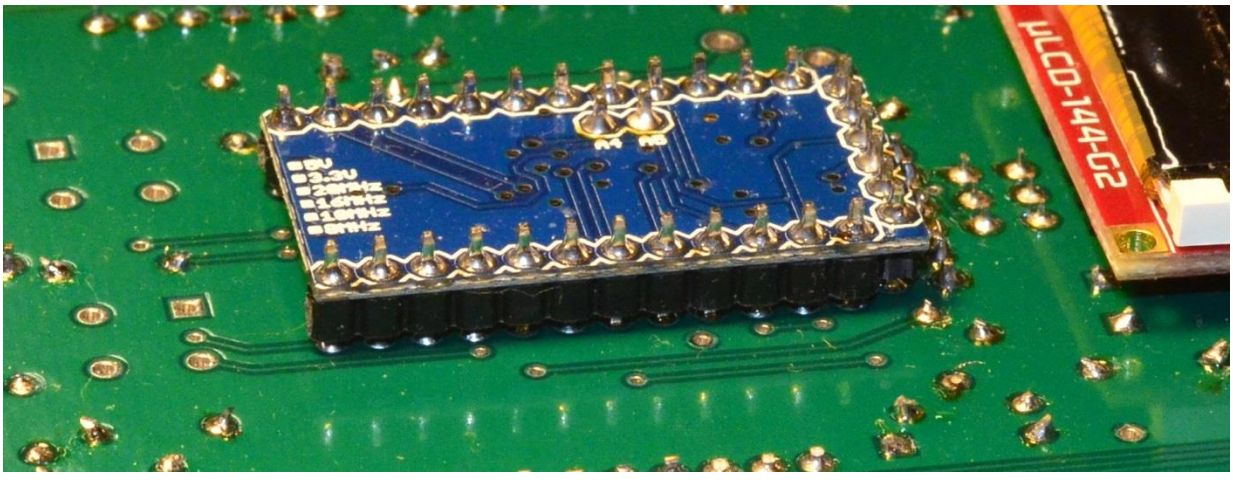
f. Group 6: Back Side Components
   i. At this point, check all your solder connections – once you place parts on the opposite side, it will be very difficult to correct any placements under then
   ii. **Note:** if you think that you MIGHT later upgrade your JuiceBox to Premium edition, you will need to place R11 and C5 components now!



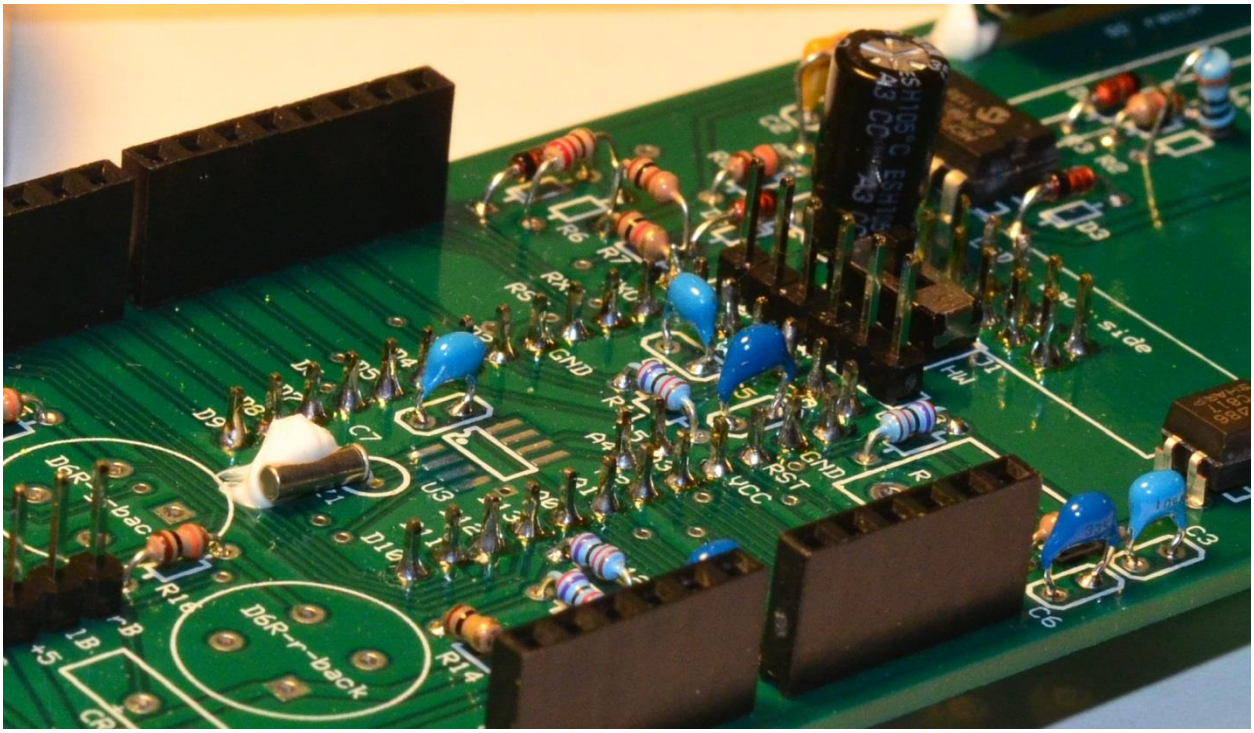
   iii. Place Arduino Pro Mini 5V
      a. Make sure all Arduino pads have pins soldered to them & those pins stick out from the COMPONENT side of the Arduino board



      b. Arduino is inserted from the Back Side of the main PCB- refer to the picture below



c. Do not insert Arduino board all the way to avoid shorting of the Arduino components to the leads of components inserted from the other side – keep 5-6mm clearance between the Arduino board and the main PCB & visually check clearance to any component leads that might be sticking out from the other side



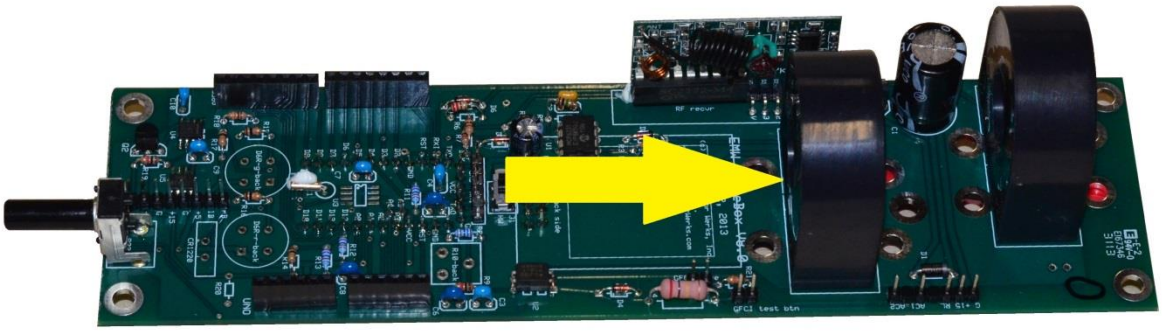
iv. Turn over to the top side of board and solder pins.

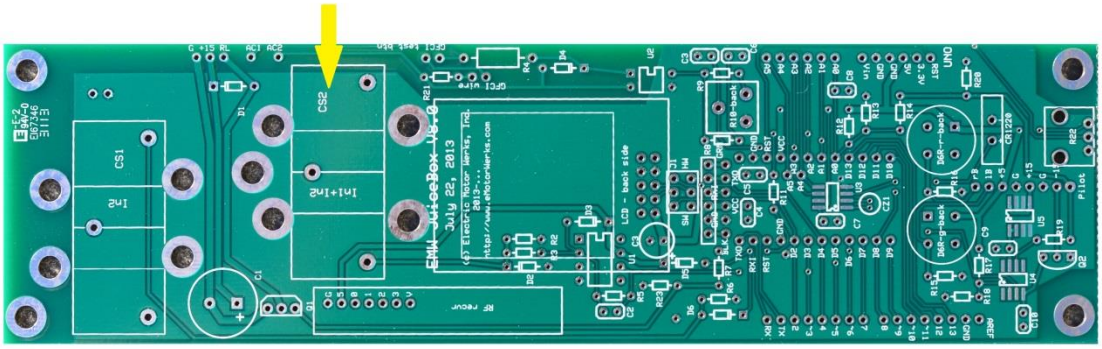
g. Group 7: Largest Top Board components

v. Back on the main component side of the board

vi. Place & solder GFCI Current Transformer: CS2*

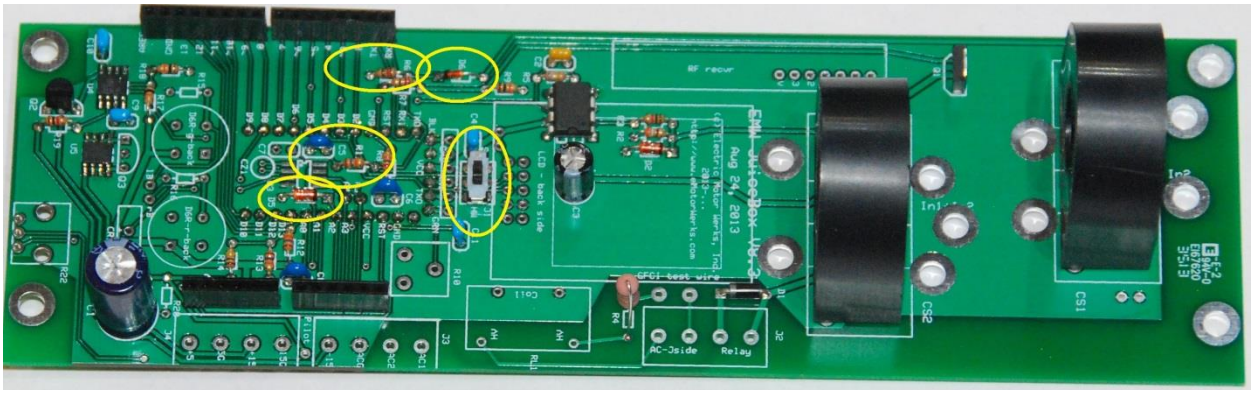
vii. Cut 4.5-5” of the signal wire, thread through the transformer you just placed, and solder the ends to the ‘GFCI test wire’ pads





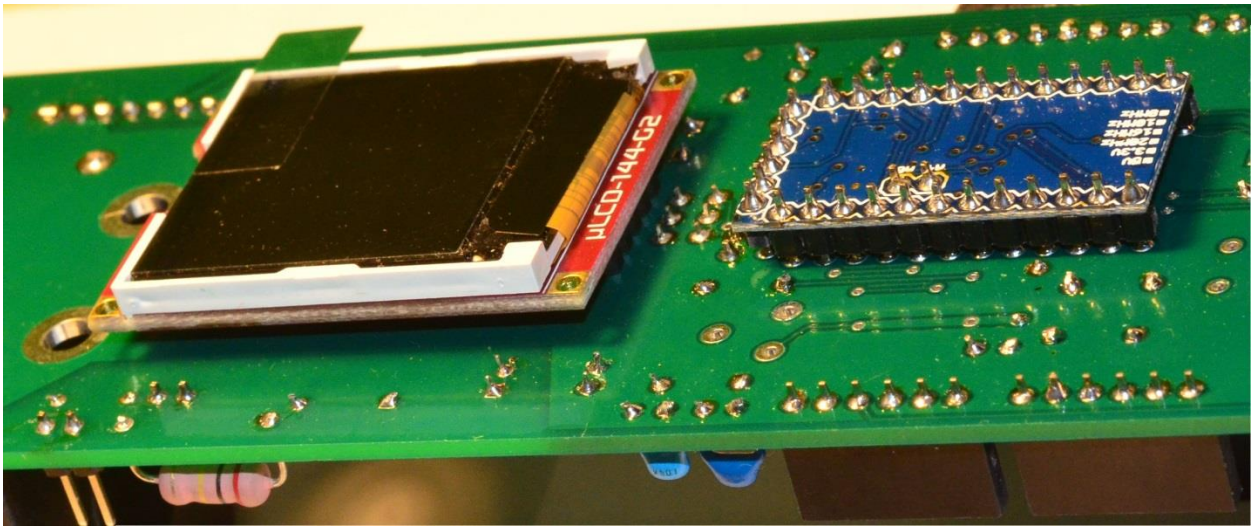
2. **Premium Edition sequence:** Above Sequence with Additional Parts. YOU HAVE TO use the Base Edition sequence and refer to this section for additional parts GROUP BY GROUP. Failure to do so will result in difficult assembly due to broken sequence of part placement!

a. Group 3: Extra Parts
    i. Place 120R: R6
    ii. Place 27k: R11
    iii. Place 3.3uF: C5
    iv. Place 3.3v zener: D5
    v. Place signal diode BAW76: D6
    vi. Place Slide Switch: J1

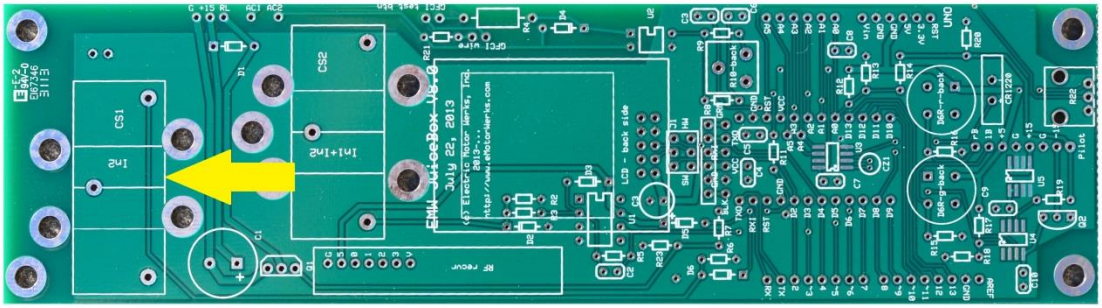


b. Group 5: Larger Top Board components
    i. Place RF Receiver: labeled on board as RF recvr, orient pins to match labeling on the board

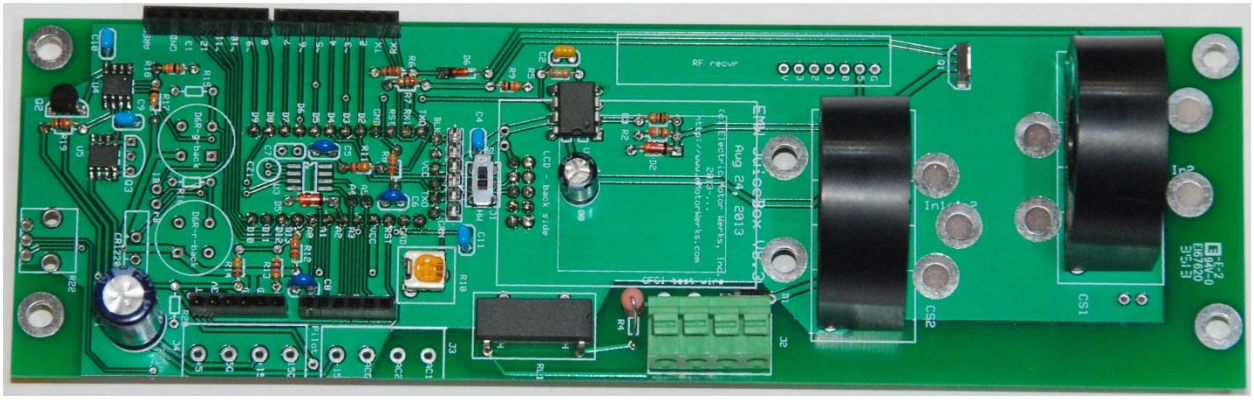
c. Group 6: Back Side Components
    i. Place LCD: labeled as LCD-Backside on top of board
    ii. Do not insert the LCD fully into the board – set LCD at ~7-8mm off the PCB surface



d. Group 7: Largest Top Board components
    a. Place Current transformer: CS1



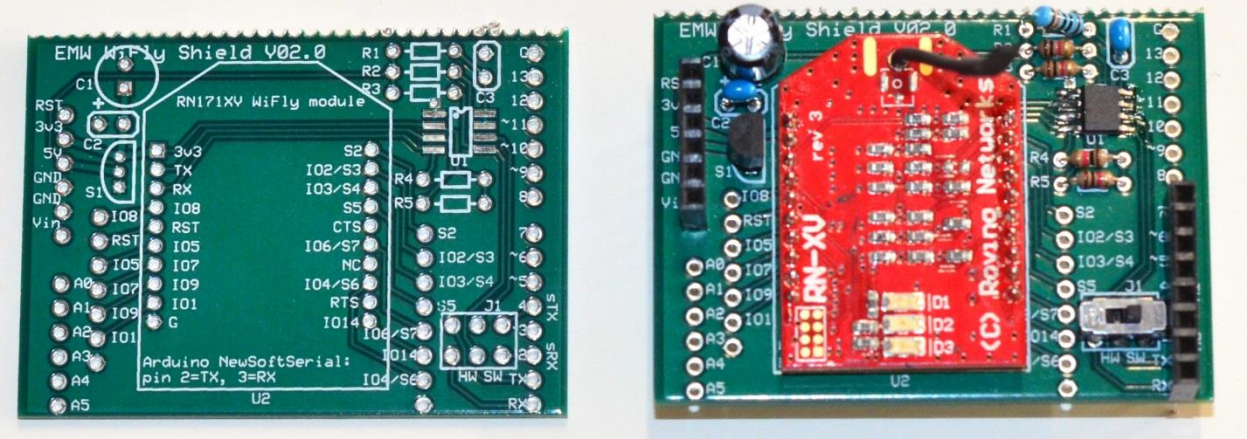
These are the completed boards (Premium GFCI versions shown without wireless received)**:**



WiFi Shield board assembly

Note: do not overheat SMD parts

1. If the main board is not yet separated from the WiFi shield board, break them apart. Use a file to remove any remaining metallization in the perforation holes
2. Group 1 – SMD components
    a. Place & solder the level translator IC (PCA9306): U1
3. Group 2 – ICs
    a. Place the WiFly module
    b. Turn over, solder
4. Group 3 - small parts that can't be fixed to the board
    a. Place & solder switch J1. This switch controls how the WiFi board is connected to the Arduino. Normally, you would connect WiFI to pins 2,4 of the Arduino for SoftSerial communication. The ONLY reason to connect WiFI to hardware serial is to program the WiFi module directly from your PC
        i. Alternatively, can install 2 3-pin male headers and use jumpers to set the connection path for WiFI module
        ii. Alternatively, if no change in connection path is expected in the future, use short pieces of wire (or component leads you cut off earlier) to short the middle pad on each row of 3-position connectors to the rightmost pad
5. Group 4 – other small parts
    a. Place 100-200k: R1
    b. Place 1k: R2, R3, R4, R5
    c. Place 10-50uF cap: C1
    d. Place 0.1uF (104) cap: C2
    e. Place 3.3v voltage regulator: S1
    f. Place long-lead female headers (2x 6-pin, 2x 8-pin)
        i. If you don't feel like soldering unnecessary pins, you can solder just 1x 6-pin and 1x 8-pin connectors (see the board to determine which connectors do have connections to the board's components)
    g. Place flat object over top of the board to hold everything in place and turn PCB over, solder pins
6. Your WiFI shield is ready to be inserted into the main board!
    a. When inserting, make sure that nothing is shorting to anything under the shield
    b. Here's a quick photo of a bare and a completed board

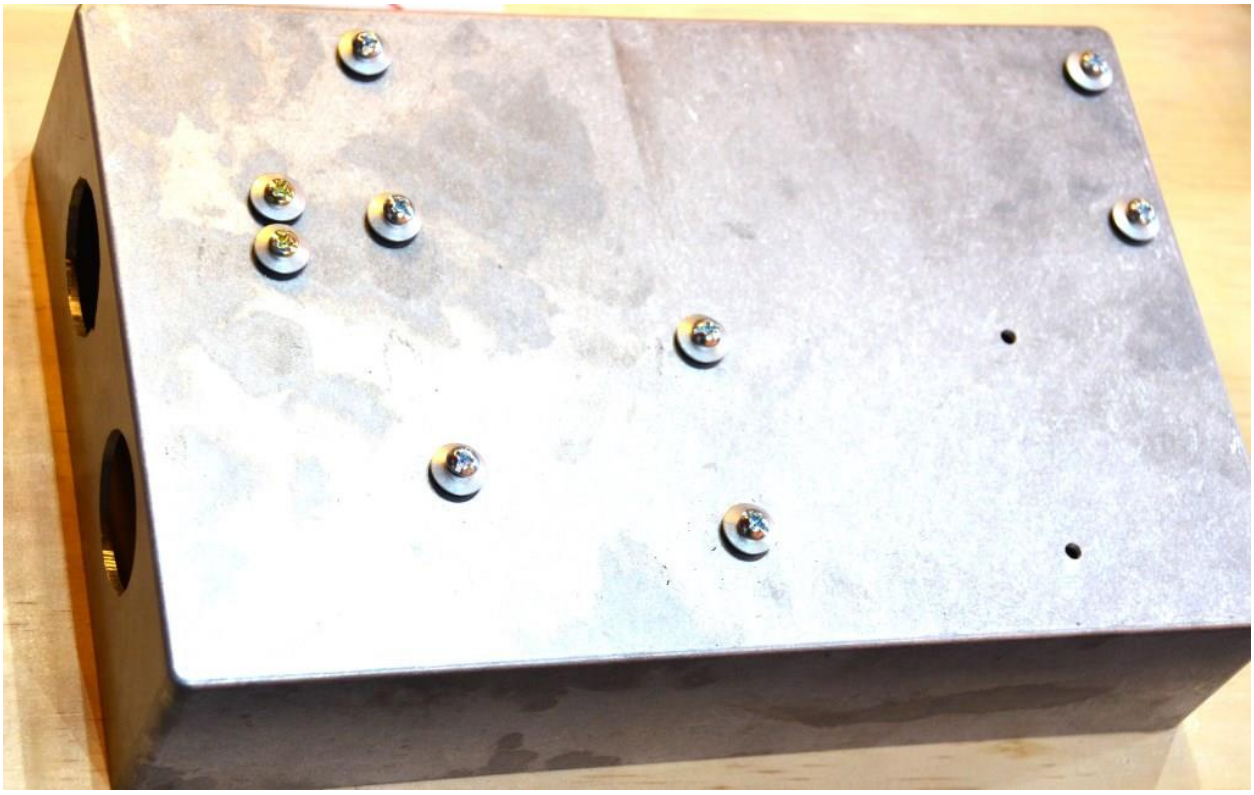

EMW WiFly Shield V02.0
RN171XV WiFly module
Arduino NewSoftSerial:
pin 2=TX, 3=RX
U2
HW SW TX
RN-XV
(C) Roving Networks
rev 3

Part 4. Prepare the enclosure

Base

Note: unless explicitly mentioned otherwise, here and in the rest of this document, enclosure is assumed to be oriented one of its shorter sides facing you, with you looking into the enclosure cavity.

1. Cut the holes for input & output cable glands
    a. Use a 1 7/16” hole saw that’s rated for aluminum (available at any home depot)
    b. You can use a 1 3/8” size if you can’t find 1 7/16”. You might need to file away a small bit of material in this case to widen the hole
    c. Position the holes slightly to the left side of the enclosure
        i. Input cable gland – center hole at 1 ¾” from the left side of the enclosure, 1” from the bottom
        ii. Output cable gland - 4” from the left, 1” from the bottom
2. Drill 7/32” mounting holes for all components
    a. Please use the CAD file below for layout of the mounting holes in the base enclosure
        i. Link to file: <COMING SOON>
        ii. File shows configuration as seen from the inside of the enclosure
        iii. You can flip the picture in CAD program if you want to drill from the back (easier)



<CAD file with hole map coming soon>

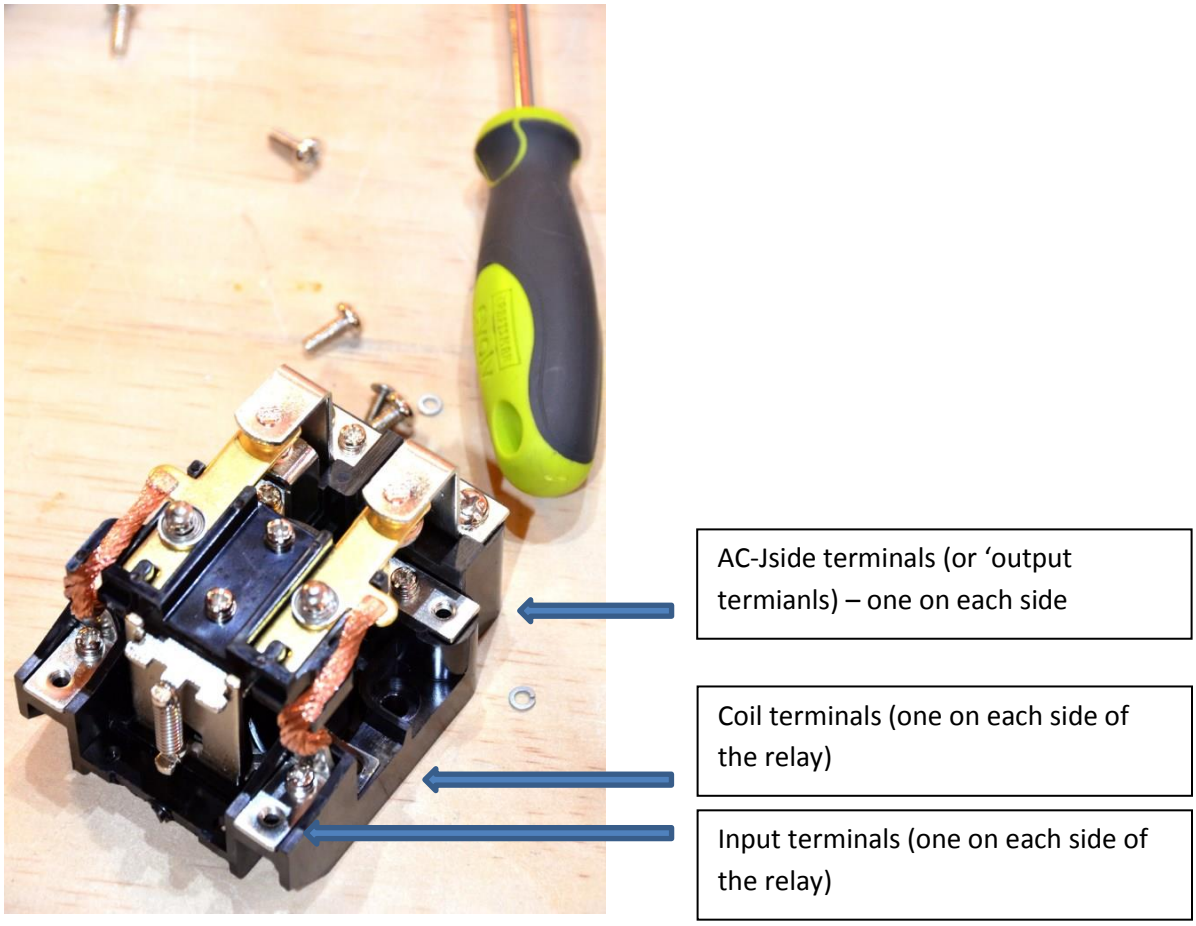
Part 5. Mounting the components to enclosure

Base

Overall mounting tips: Use the supplied sealer washers on all screws entering the enclosure. When used correctly, these will preserve the waterproof status of the enclosure. The main requirement is to tighten the screws to just the right torque so that the conical aluminum washer becomes flat – see photo below.

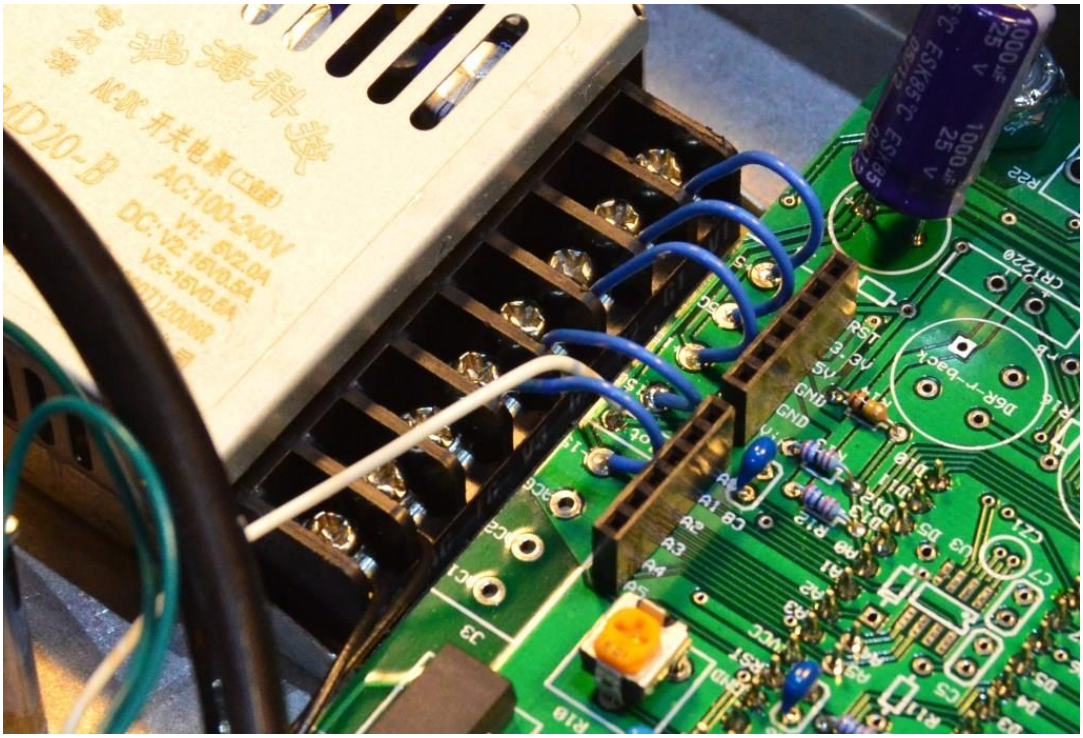
In this photo, the washer on the left is not tightened, the washer on the far right is tightened just to the right amount of torque

1. Mount the Relay
    a. Remove terminal screws from the common terminals (bottom terminals on the picture), coil terminals (next ones towards the top), and bottom contact terminals (next ones towards the top)



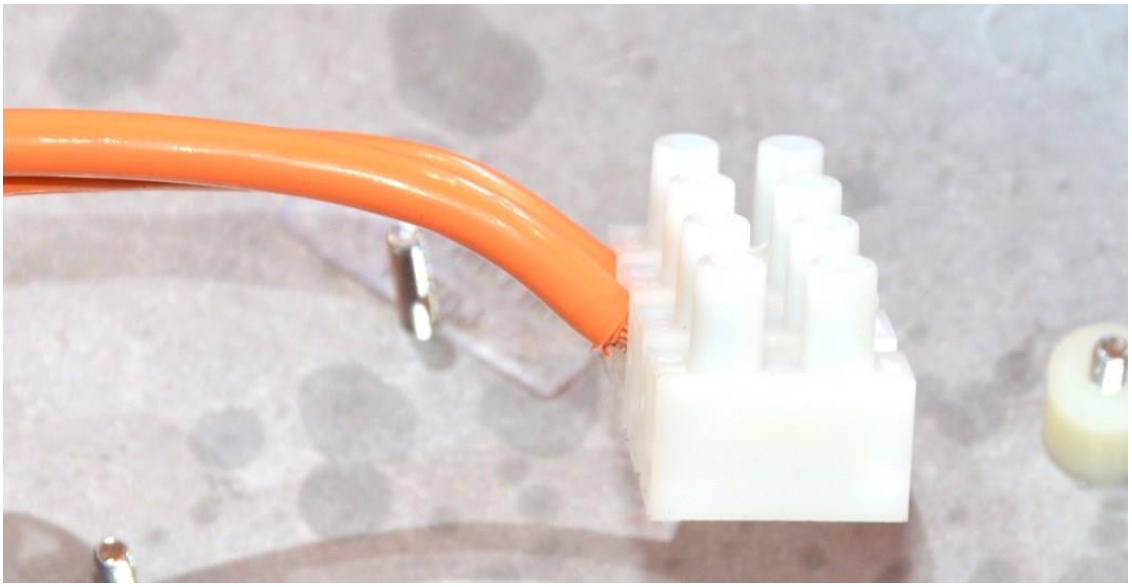
b. Orient relay with the common terminals facing DOWN
c. Using 2x 1-inch long 8-32 machine screws and lock nuts, mount the relay inside the enclosure

2. Wire power supply to the PCB
    a. Prepare 5x 1.5-2” signal wires (solid AWG 20-24 are easiest to deal with in this application)
    b. Solder one end of the wires to the board connectors J3 and J4 (use all positions in J4 and only ‘-15’ position in J3)
    c. Insert the other ends into the power supply – orient supply facing the PCB. The order of J3/J4’s positions is the same as the order of the terminals on the supply. Double-check against markings on board and supply
    d. Prepare 6” and 8” signal wire, connect one end to the AC terminals of the power supply – one wire to each terminal. Twist the first 4” of the wires
    e. Prepare 4” of signal wire, solder one end to one of the ground pads on the top of the board (near CS1). This will be the ground signal wire.
        i. This is no longer required in V8.6 boards – the board is grounded via mounting bolts



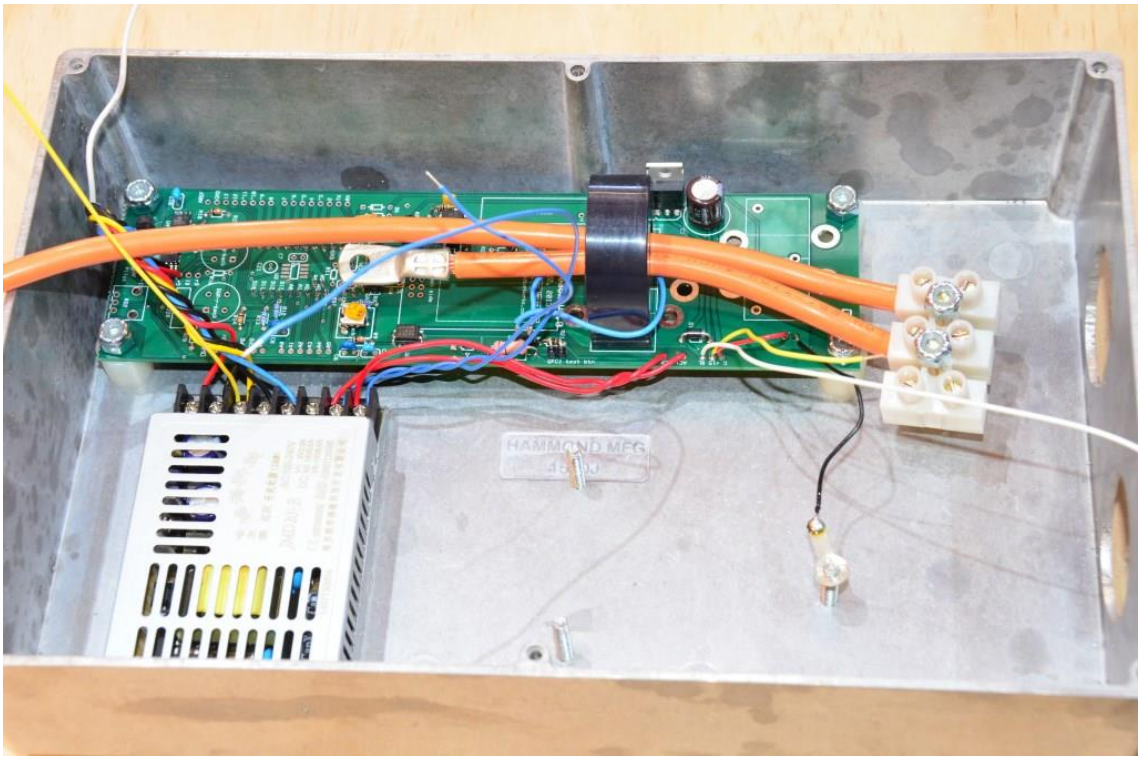
3. Prepare wiring for the relay
    a. Use 3” and 8” signal wires for the 2 relay positions of J2 connector – these will later be connected to the relay coil
    b. Use another set of same length wires for the 2 AC-Jside positions of J2 connector – these will later be connected to the NO (Normally Opened) relay terminals
    c. Solder one end of all wires to the PCB (or insert into the J2 connector if it’s already placed on your board – you need to push on the locking tab from the top and insert the wire then release the tab). Twist the first 1.5-2” of the wires

4. Prepare internal power wiring
    a. Line 1
        i. Use 6-8” of AWG 6 wire
        ii. Fit a proper lug (with #8 / #10 mounting hole) on one end of the wire, keep the other end bare (1/2” or so)
        iii. Insert the bare end into the position 2 of the output terminal strip (assuming a 3-terminal strip, counting from the left), fasten
    b. Line 2
        i. Use 10-12” of AWG 6 wire
        ii. Fit a proper lug (with #8 / #10 hole) on one end of the wire, keep the other end bare (1/2” or so)
        iii. Insert the bare end into the position 3 of the output terminal strip
    c. Bend the wires upwards from the output terminal and then back to horizontal – see photo:



d. Thread both lines through a CS2 current sensor

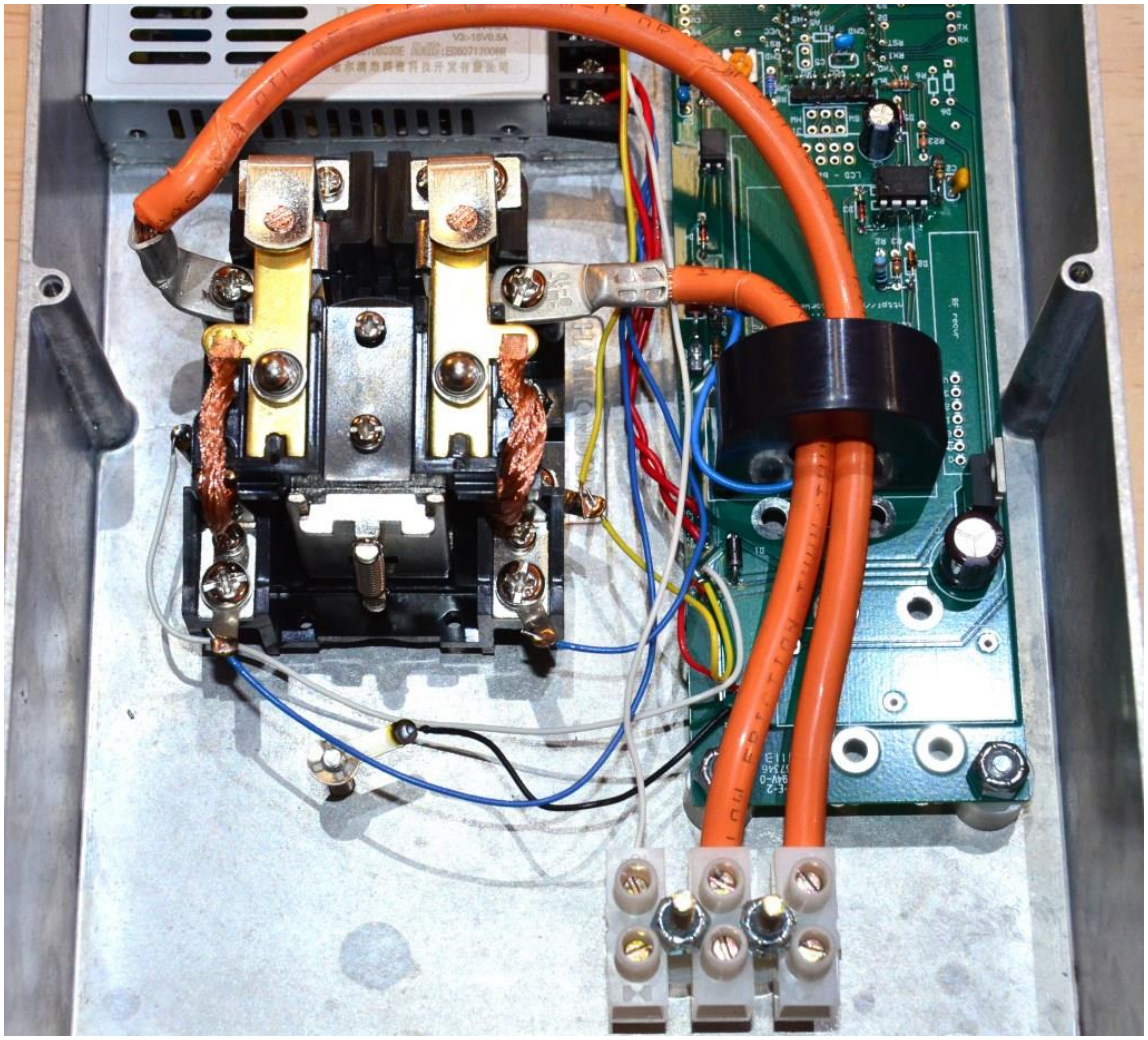
5. Mount the PCB / power supply / internal wiring assembly
    a. For PCB, use 4x 1-inch long 8-32 machine screws, 3/8-1/2-inch nylon spacers, and locknuts
    b. Orient PCB with the current sensors facing DOWN, close to the JuiceBox cable entrance
    c. For power supply, use 2x ½-inch long 4-40 machine screws and washers
    d. For output terminal, use 2x 1-2” 8-32 machine screws and locknuts

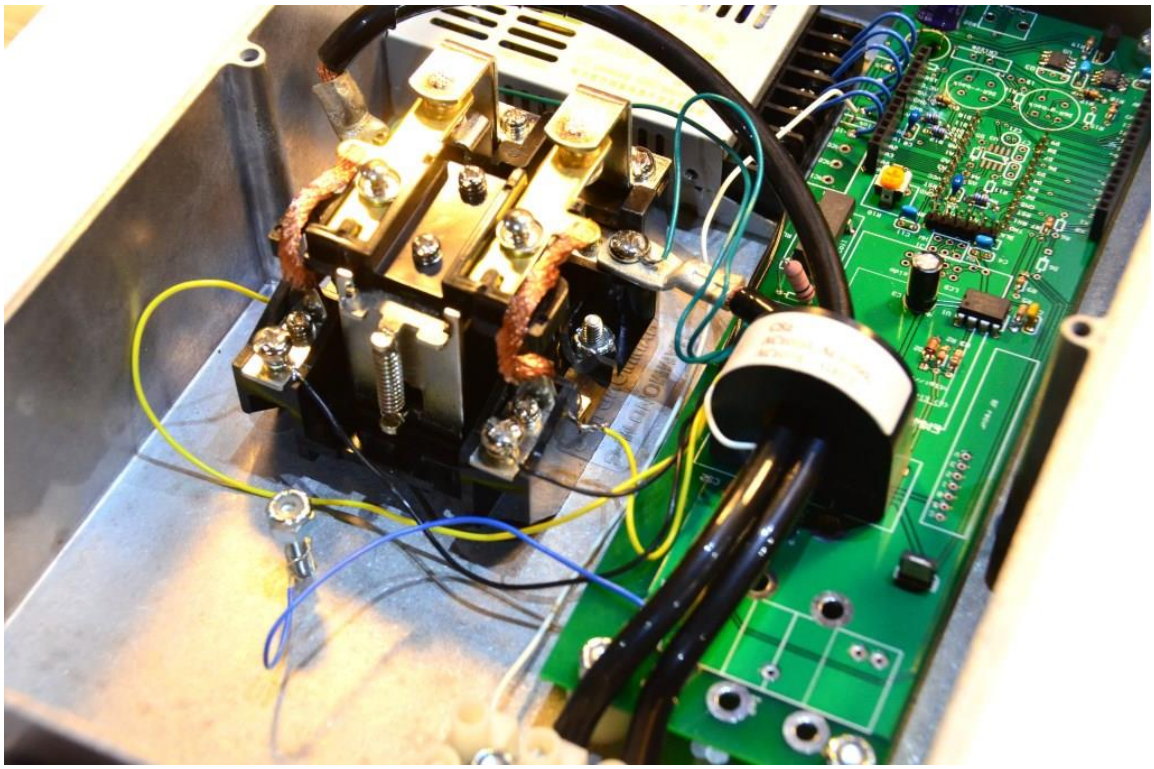


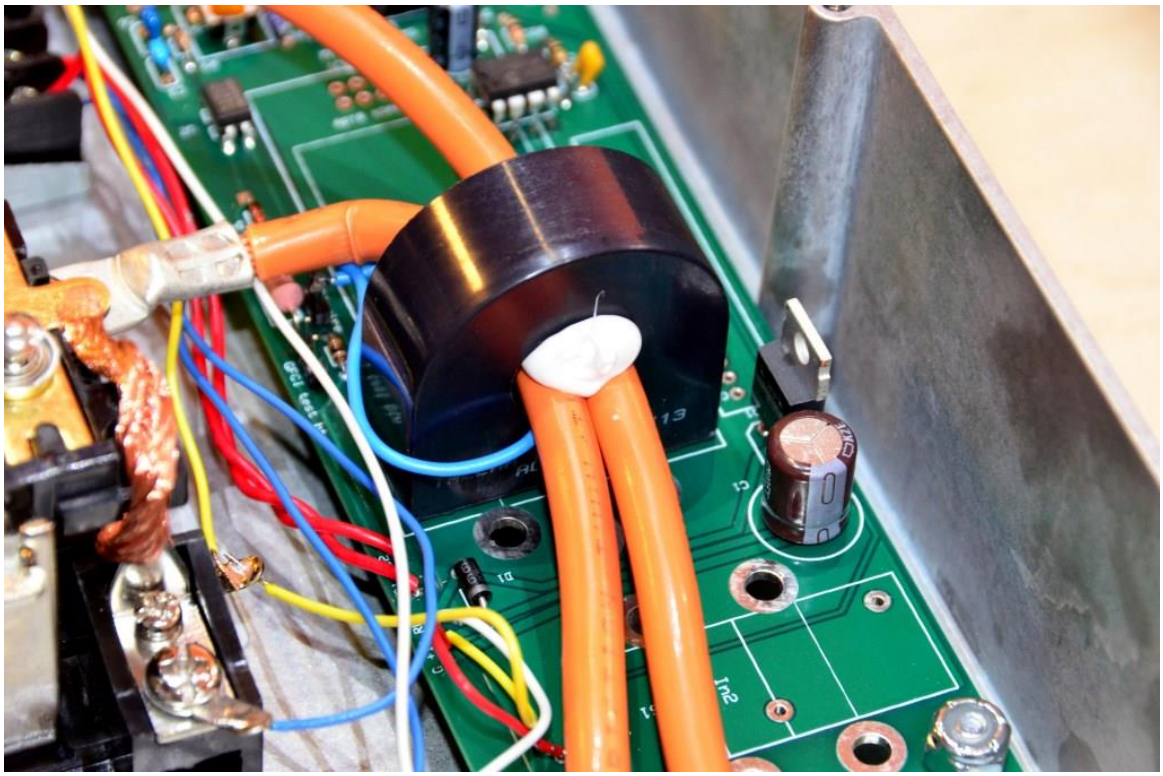
6. Wire the pilot line
    a. For V8.3 boards:
        i. The pilot solder pad is located between J3 and J4 connectors on the right side of the board
        ii. Solder a 12”-long signal wire to this pad
    b. For V8.6 boards:
        i. The pilot solder pad is located in the top right corner of the board
        ii. Solder a 3”-long signal wire to this pad
    c. Connect the pilot wire to position 1 of the output terminal strip

7. Connect coil wires to the relay
    a. These are the wires coming from the ‘Relay’ positions of J2 connector on the PCB
    b. Coil terminals are the lowest (closest to the relay’s base). See the relay photo above for reference. You can also ID them by measuring resistance between each pair of terminals (between left and right terminal in a pair) – the one with non-infinite resistance is the coil terminal pair

8. Connect internal power wiring to relay
    a. Short line 1
        i. Sharply bend the shorter AWG6 wire to the left after it exits the current sensor
        ii. Connect to the right relay terminal for the bottom (NO – Normally Open) output contact set (see photo), together with one of the AC wires from the J2 connector
            1. You may need to bend a lug slightly to avoid interfering with the J2 connector
    b. Long line 2
        i. Bend the longer AWG6 wire to the left to arc over to the left relay terminal for the bottom contact set
        ii. Bend the lug so that the wire exits the relay in the upward direction (see picture below)
        iii. Connect to the left relay relay terminal for the bottom (NO – Normally Open) output contact set (see photo), together with the second AC wire from the J2 connector
    c. Ensure that the wires pass through the current sensor as parallel as possible, and are at the same height from the base of the sensor. Failure to do this will likely cause false trips of the GFCI circuit above ~20-30A output
    d. Secure the wires’ position in the sensor with some silicone sealant



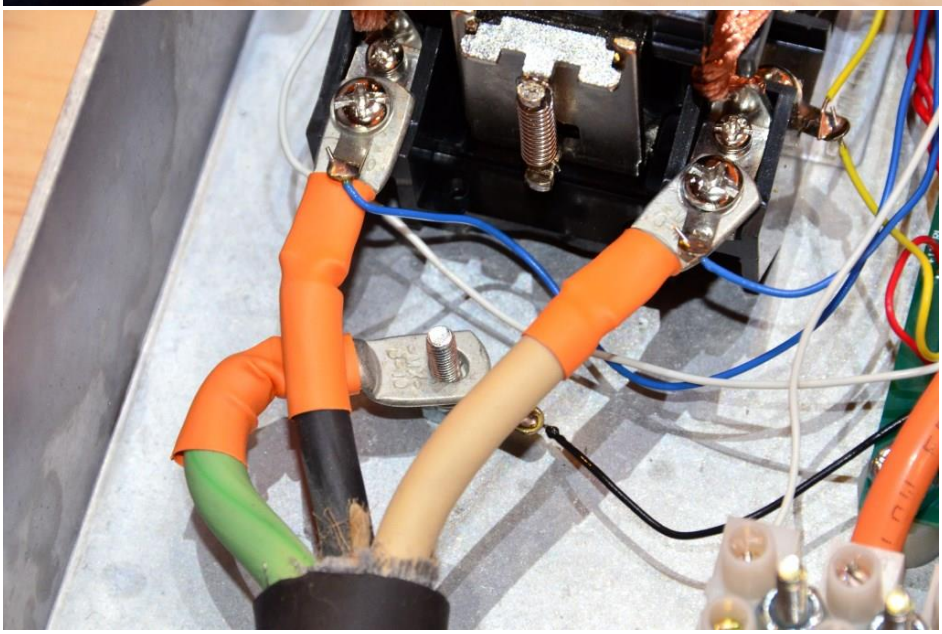




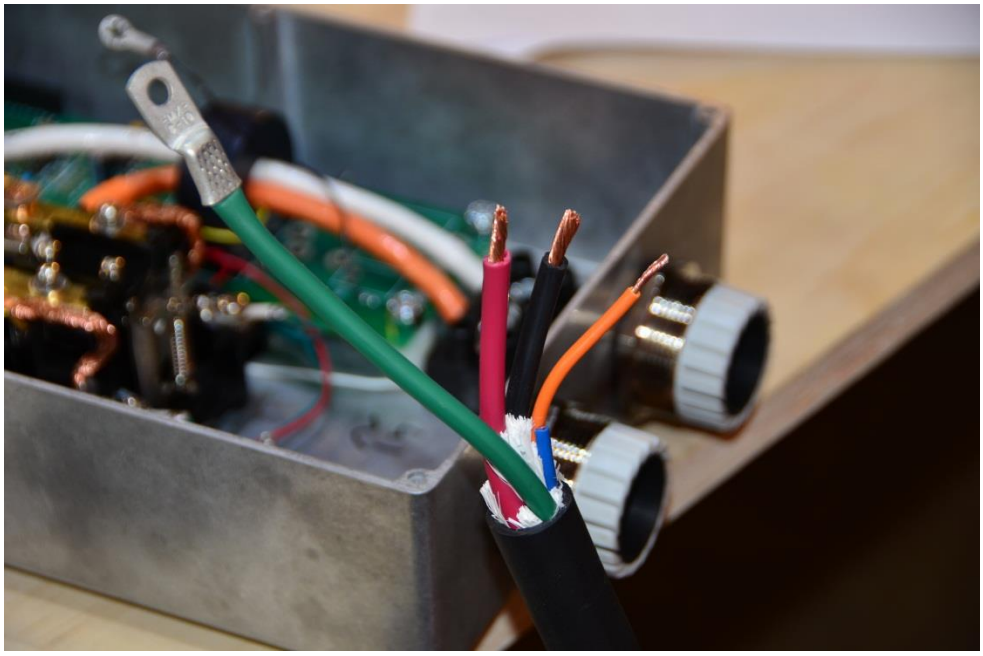
9. Connect the input cable
    a. Remove ~4” of the outer cable jacket

United States	 **PHASE** **Signal (120/208/240V)**	 **(120/208/240V)** **NEUTRAL**	 **(*green*)** **GROUND**

    b. Strip ~1.5” of isolation from all three wires (phase, neutral, ground)
    c. Fit 3 lugs with #8 / #10 mounting holes to the hot (phase & neutral) and ground lines of the input cable
    d. Thread the input cable through the input cable gland (left gland)
    e. Bolt one of the hot lines and one of the AC signal wires (the one going to the power supply) onto one of the relay’s common positions
        i. Make sure that the high-current wire contacts the relay pad directly (i.e. AC1 wire is NOT in between the relay pad and the hot line input)
    f. Bolt the other hot line and AC signal wire onto the other relay’s common position
    g. Place the ground wire from input cable onto the ground post - along with a ground signal wire from the PCB



10. Connect the output J1772 cable
    a. Strip ~4” of outer cable jacket
    b. Leave Ground wire 4” and cut 2” from rest of the wires
    c. Strip ~1/2” of the isolation from all 5 wires
    d. Crimp lug to Ground wire
       Measure the resistance between Ground Wire (Green) and smaller gauge wires. Cut out wire that has 150 Ohm resistance with the Ground. Smaller gauge wire that has no connection to Ground (or infinite resistance) is the “Pilot” wire – that’s the one you need to use.

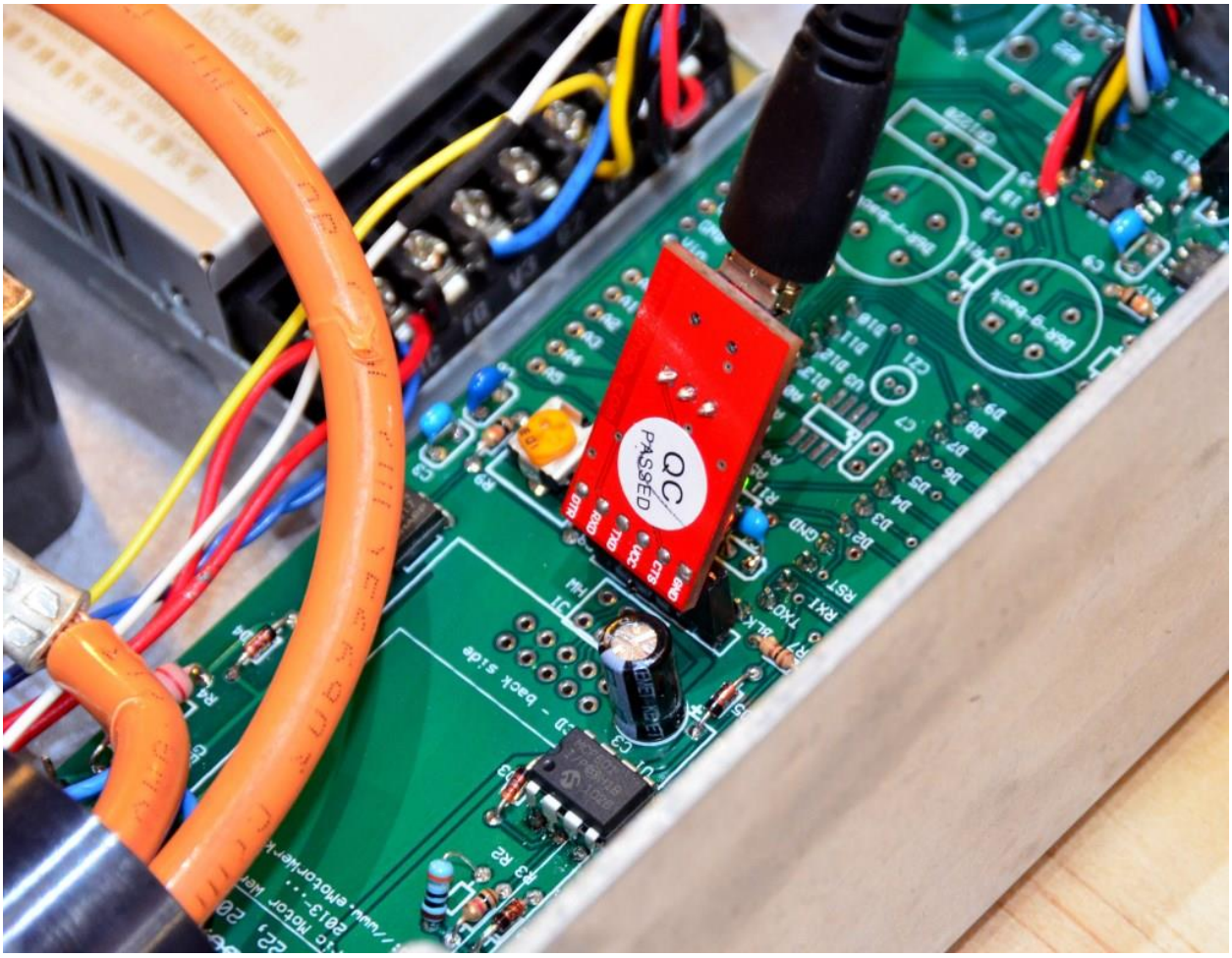


e. Thread the cable end through the output cable gland (right)
f. Connect wires to the output terminal
    i. Hot lines to positions 2 and 3
    ii. Pilot to position 1
g. Connect J1772 Ground onto the ground post and fasten using a locknut

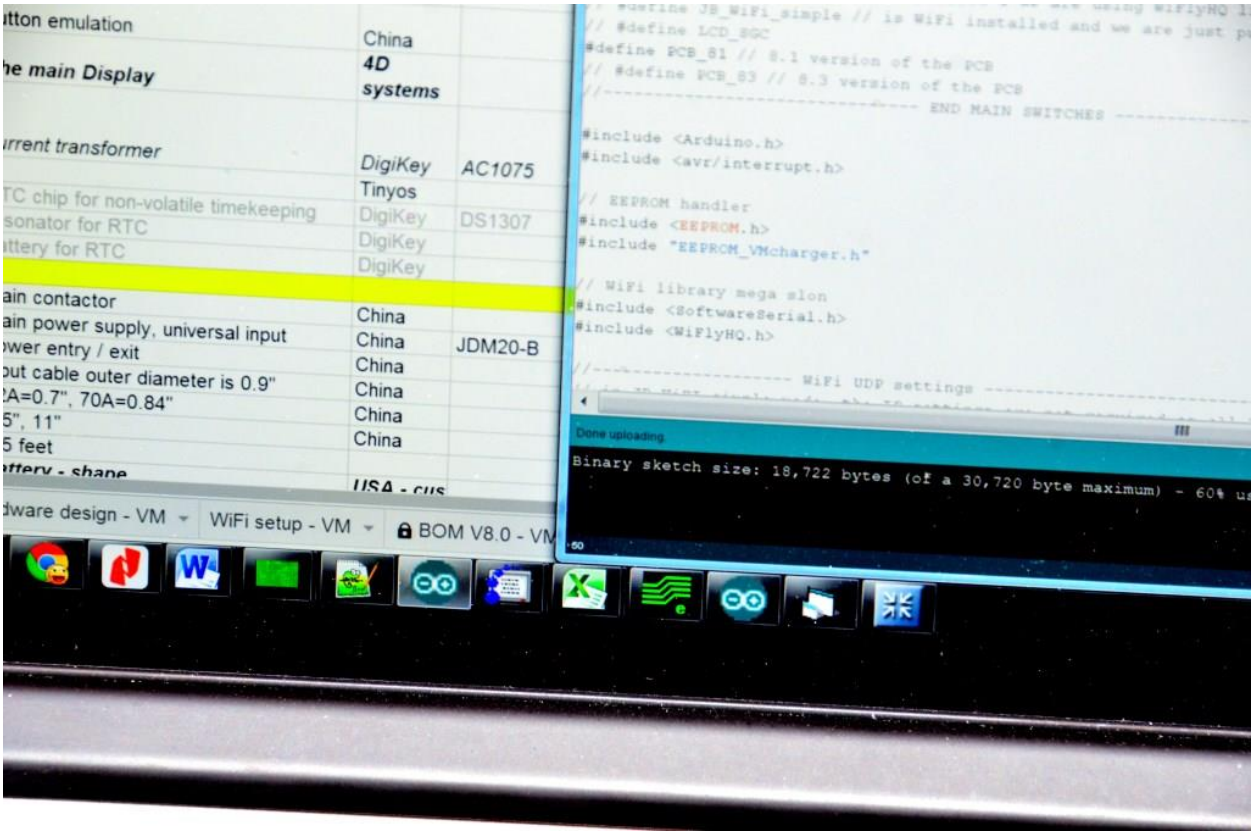
11. Tighten the input and output glands to that the cables cannot be moved by pulling / pushing from outside

Part 7. Programming the Arduino

1. Install Arduino environment on your PC
    a. Firmware currently tested on Arduino V1.5.2
        i. Should work in any 1.0 or later versions, as well
2. Connect the supplied FTDI cable to your PC
3. Make sure your PC recognizes the cable and assigns it a separate COM port
4. Download firmware from the EMW site (in Firmware folder)
    a. Required libraries: TimerOne, uLCD144_SPE (files provided in the Firmware folder at http://www.emotorwerks.com/JuiceBox_Public/ - make sure you select the right version folder)
    b. Copy all the libraries into your Arduino libraries folder (default location is C:\Arduino\libraries\
    c. Download the latest firmware (.ino and .h file in the same folder). Create a folder called 'EMW_EVSE_firmware' and place the files there
    d. Open the main firmware in Arduino IDE
5. Make sure your downloaded code is configured correctly for your version of the charger kit
    a. File->Tools->Board, select 'Arduino Pro or Pro Mini' as the board type
    b. File->Tools->Processor, select 'ATmega 328 (5V, 16MHz)'
    c. Check the "#define …" statements in the first 2 pages of the code (marked as '---------- MAIN SWITCHES ----------')
        i. Comment out '#define DEBUG'
        ii. Uncomment '#define AC1075'
        iii. If you have a WiFi shield you got from us, uncomment '#define JB_WiFi_simple'
            1. You might want to initially leave this commented out and first make sure that the JuiceBox works as expected without WiFi support
            2. Then, once you confirm operation without WiFi, you can enable WiFi code by uncommenting the switch
        iv. If your kit came with a programmed Arduino, it will be programmed with non-DEBUG, AC1075, non-WiFi configuration
6. Upload the code to the EVSE
    a. Connect the FTDI board to the programming header on the main PCB
        i. Align the FTDI so than 'GND' on FTDI connector plugs into the 'BLK' position on the programming header



b. If you have a premium version / WiFI shield, ensure that BOTH slide switches (by the LCD and on the WiFi shield) are flipped into ‘SW’ position. If not done, they will interfere with the upload
c. In Arduino IDE, click Compile icon, confirm error-less compilation
d. Click Upload icon, confirm error-less upload


tton emulation
China
he main Display
4D systems
rrent transformer
DigiKey
AC1075
Tinyos
TC chip for non-volatile timekeeping
DigiKey
DS1307
sonator for RTC
DigiKey
ttery for RTC
DigiKey
ain contactor
China
ain power supply, universal input
China
JDM20-B
wer entry / exit
China
ut cable outer diameter is 0.9"
China
A=0.7", 70A=0.84"
China
5", 11"
China
5 feet
China
ttery - shape
USA - cus
dware design - VM
WiFi setup - VM
BOM V8.0 - VM
#define JB_WiFi_simple // is WiFi installed and we are just p
// #define LCD_SGC
#define PCB_81 // 8.1 version of the PCB
// #define PCB_83 // 8.3 version of the PCB
END MAIN SWITCHES
#include <Arduino.h>
#include <avr/interrupt.h>
// EEPROM handler
#include <EEPROM.h>
#include "EEPROM_VMcharger.h"
// WiFi library mega slon
#include <SoftwareSerial.h>
#include <WiFlyHQ.h>
WiFi UDP settings
Done uploading.
Binary sketch size: 18,722 bytes (of a 30,720 byte maximum) - 60%

Part 8. Logic test

1. Disconnect FTDI header
2. If you have a Premium version, flip the LCD slide switch back to 'HW' position
3. Connect FTDI to the main PCB programming header. Do not connect input AC power to the JuiceBox yet
4. From Arduino IDE, launch a Serial Monitor (Tools menu)
5. The board should reset and start outputting info into the Serial Monitor
    a. Depending on the Edition of JuiceBox, the output may be slightly different from what is shown below
    b. Regardless of the format, after ~5-10 seconds past reset you should see the ~1/second printout of the main parameters (voltage, current settings, etc)
    c. Turn the current setting trimpot. The current setting should change accordingly. Set a desired value for your configuration.
        i. If the trimpot is at the far left position, the current will be set to a default 30A output
        ii. Otherwise, the setting is linear to the angle of the trimpot
            1. The range is from 0A (trimpot position just to the right of the left stop) to 60A max current (right stop).
            2. Example: you want to setup your JuiceBox to draw 40A: 40A is 2/3rd of 60A full range -> Turn the trimpot 2/3rd to the right -> confirm in the Serial monitor
6. Test J1772 operation. There are 2 options:
    a. Build a small test rig (optional but preferred as it will allow to test operation to a larger extent)
    b. Just use your EV
7. Option 1 – build a small test rig
    a. You will use a few combinations of resistors and diodes to simulate various states of J1772 on the car side
        i. You will be connecting all these combinations between the pilot output and ground
        ii. If a combo has a diode, you would be connecting the diode's anode towards the pilot output line (not the ground)
    b. "Something is connected but not a proper J1772 load (e.g., fingers)"
        i. Use a 1k resistor
    c. "Car connected"
        i. Use a small signal diode and 2.7k resistor in series
    d. "Car requests power"
        i. Use a small signal diode and 1k resistor in series
    e. Using the above combinations, imitate the car sequence below in Option 2
        i. The additional important feature you will be testing with this rig is the ability of your JuiceBox to recognize the dangerious situation of non-J1772 load being connected to the J plug (could be child's fingers, or some water creating low-impedance path, etc)
8. Option 2 – just use your EV
    a. **Ensure you follow proper High Voltage safety procedures**

i. Wear rubber-soled shoes
ii. Treat every exposed terminal / pin / PCB trace as live high-voltage terminal – EVEN IF YOU 'KNOW' IT IS NOT CONNECTED
iii. Never touch any two terminals at the same time.
    1. Best practice is to do ANY work on the circuit with one hand once the circuit is energized.
    2. This prevents you from creating an electrical path between your hands – the most dangerous of all as it passes through your chest
iv. If you need to use two hands or handle the circuit, unplug everything (input AND output) and measure voltage on the input and output lines before touching anything (there are no high-voltage capacitors in the JuiceBox so at least that type of danger does not exist)
v. Be very careful connecting any AC-powered equipment to the circuit when circuit is energized
    1. Main danger is connecting the equipment ground to live AC line
    2. Most often happens with scopes (e.g., attempt to measure voltage between the two hot AC lines), solder guns
    3. If absolutely needed to make such connections while circuit is live, use battery-operated equipment
vi. Wear protective shop glasses

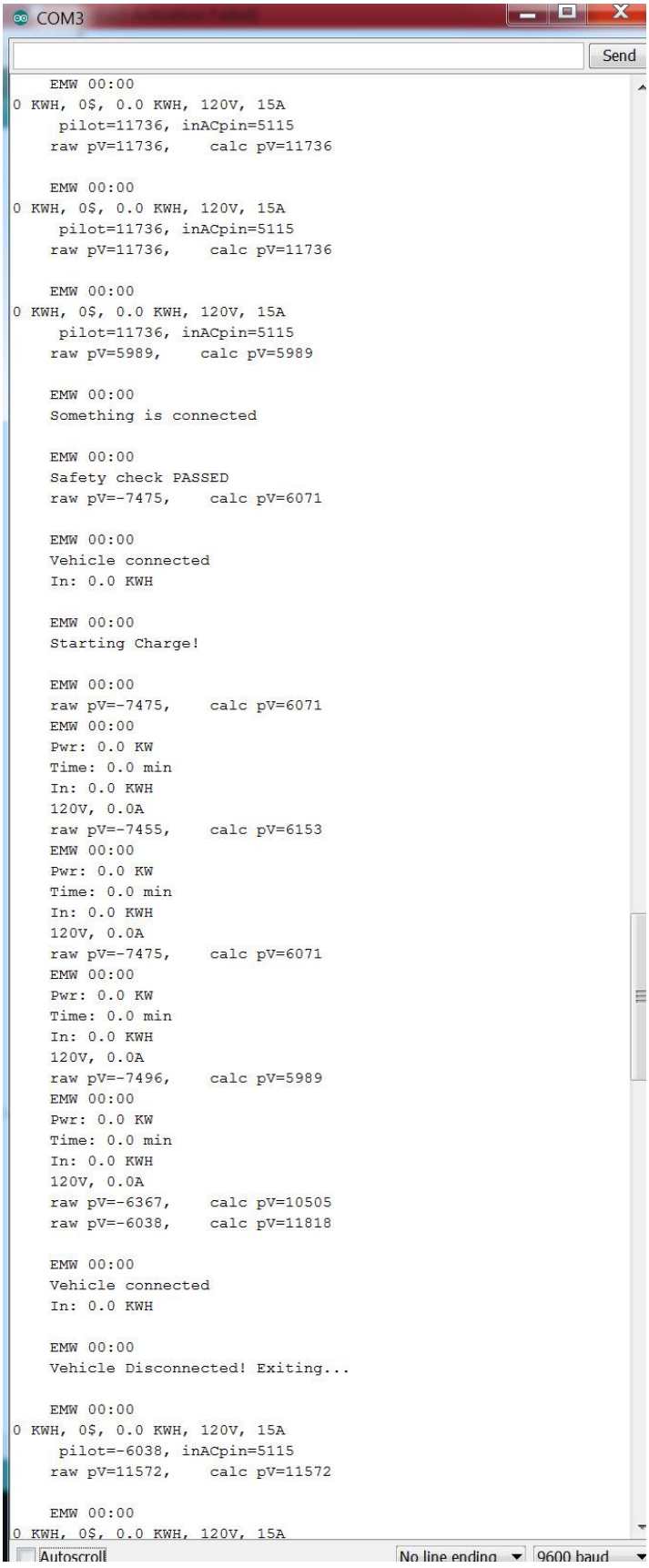
b. Remove FTDI header from the board
    i. If you'd like to monitor the JuiceBox over Serial monitor while the AC is applied, you need to remove a small jumper from the FTDI board. Otherwise the USB power supply will be fighting the JuiceBox power supply on the 5V line and supply voltages get unreliable
c. Connect 120V AC to your JuiceBox (always start testing at lower voltages and through a protective power strip)
d. Wait for 15-30 seconds to make sure all initialization processes complete
e. Measure (or monitor with a scope) the voltage on the pilot pin of the main PCB
    i. Should show ~12V
f. Connect the J1772 plug into your car
g. Your car should recognize the JuiceBox and request power
    i. You should see a momentary dip of the pilot voltage to ~9V
    ii. JuiceBox should turn on the 50% duty +/-12V square wave on the pilot to test for diode on the car side (you will see this on the scope as -12V to +9V square wave)
    iii. You should see a further dip of the top of the square wave to ~6V as the car requests power
    iv. Juicebox will change the duty cycle to match your current setting
    v. Juicebox will close the main relay
    vi. Car will indicate charging
h. Test charge interruption
    i. Press a button on the J plug (but do not remove yet)
    ii. The top of the wave on pilot signal should go back to 9V ('car connected)
    iii. Remove the plug
    iv. The top of the wave should go back to 12V
    v. The pilot line will turn solid 12V (no wave) shortly

vi. The power relay should open, disconnecting output power
vii. Re-connect the plug
viii. Charge initiation sequence from the previous step should repeat and car should restart charging

i. Test GFCI interruption
    i. Using small isolated screwdriver, briefly short the GFCI test button pins on the main PCB
    ii. The relay should open immediately
    iii. LCD should show (Premium version only) that GFCI has tripped
    iv. GFCI will re-attempt in 15 min (unless DEBUG flag is set in the firmware in which case the connection will be re-attempted immediately)

Here's an example of the Serial Monitor Output

Transition from standby (J1772 state A) to vehicle connected & requesting power (state C) and back is shown (Base unit)


COM3
Send
EMW 00:00
0 KWH, 0$, 0.0 KWH, 120V, 15A
pilot=11736, inACpin=5115
raw pV=11736, calc pV=11736
EMW 00:00
0 KWH, 0$, 0.0 KWH, 120V, 15A
pilot=11736, inACpin=5115
raw pV=11736, calc pV=11736
EMW 00:00
0 KWH, 0$, 0.0 KWH, 120V, 15A
pilot=11736, inACpin=5115
raw pV=5989, calc pV=5989
EMW 00:00
Something is connected
EMW 00:00
Safety check PASSED
raw pV=-7475, calc pV=6071
EMW 00:00
Vehicle connected
In: 0.0 KWH
EMW 00:00
Starting Charge!
EMW 00:00
raw pV=-7475, calc pV=6071
EMW 00:00
Pwr: 0.0 KW
Time: 0.0 min
In: 0.0 KWH
120V, 0.0A
raw pV=-7455, calc pV=6153
EMW 00:00
Pwr: 0.0 KW
Time: 0.0 min
In: 0.0 KWH
120V, 0.0A
raw pV=-7475, calc pV=6071
EMW 00:00
Pwr: 0.0 KW
Time: 0.0 min
In: 0.0 KWH
120V, 0.0A
raw pV=-7496, calc pV=5989
EMW 00:00
Pwr: 0.0 KW
Time: 0.0 min
In: 0.0 KWH
120V, 0.0A
raw pV=-6367, calc pV=10505
raw pV=-6038, calc pV=11818
EMW 00:00
Vehicle connected
In: 0.0 KWH
EMW 00:00
Vehicle Disconnected! Exiting...
EMW 00:00
0 KWH, 0$, 0.0 KWH, 120V, 15A
pilot=-6038, inACpin=5115
raw pV=11572, calc pV=11572
EMW 00:00
0 KWH, 0$, 0.0 KWH, 120V, 15A
Autoscroll
No line ending
9600 baud

Part 9. Full Power Test

1. **Ensure you follow proper High Voltage safety procedures**
    a. **Wear rubber-soled shoes**
    b. **Wear protective goggles**
    c. **Do not touch any terminals – even if you 'know' they are not live**
2. MAKE SURE ALL THE CONNECTIONS ARE TIGHT – double-check all the high-voltage connections – one loose connection in a high-current circuit will likely mean overheating wires and melted isolation within a couple of minutes!
3. Place a current clamp-meter on one of the input lines
4. Plug in your JuiceBox into the 240V outlet
5. Wait 15-30 seconds
6. Plug your J1772 output into the car
7. Confirm charging by your car's charging indicators
8. Monitor charging current on clamp meter
    a. If Premium edition, confirm agreement with the onboard current sensor (shown on LCD display)
    b. Confirm expected charging current (e.g., ~30A for a 6.6kW Nissan Leaf charger)
9. Monitor temperature every 1-2 minutes in the first 30 minutes of charge
    a. Use infrared thermometer
    b. Check all potential heat producers in a circular pattern following the power flow
        i. Input wires as they enter the relay
        ii. Relay wiring and contacts
        iii. Power wiring (all AWG 6 wiring)
        iv. Output wires as they enter and exit the output terminal strip
    c. All contacts / wiring should show no more than 20C above ambient at any output current setting within 30 min
10. Monitor temperature every 15-30 min after the first 30 min until the end of charge
    a. All contacts / wiring should show no more than 30C above ambient at any output current setting

Part 10: Mounting your JuiceBox

BASE Edition:

In some of the early kits, we have pre-drilled 2 holes located on the vertical centerline of the enclosure. These should be the only 2 holes that are not yet occupied with the components.

For most recent kits, we are no longer drilling these holes to allow you the flexibility of mounting the boxes. In that case, adapt the mounting to your specific situations.

You can use a number of different techniques to mount the enclosure

1. Directly to a wall / post (just make sure you use a spacer between the box and the mounting surface to avoid any gaps for moisture to enter (especially in the outdoor installations)
2. Via a mounting bracket – you could get a 15" piece of ½"-wide ¼" thick aluminum rectangular bar (such as http://www.onlinemetals.com/merchant.cfm?pid=19552&step=4&showunits=inches&id=997&top_cat=60 or similar) and mount it to the back of the unit and then use the ends of the bar to mount to any surface.

For full weather protection, use a silicone sealant around your bolts to seal off the water.

Congrats!

You now have one of the best EVSEs money can buy.

More powerful.

More extensible.

More mobile.

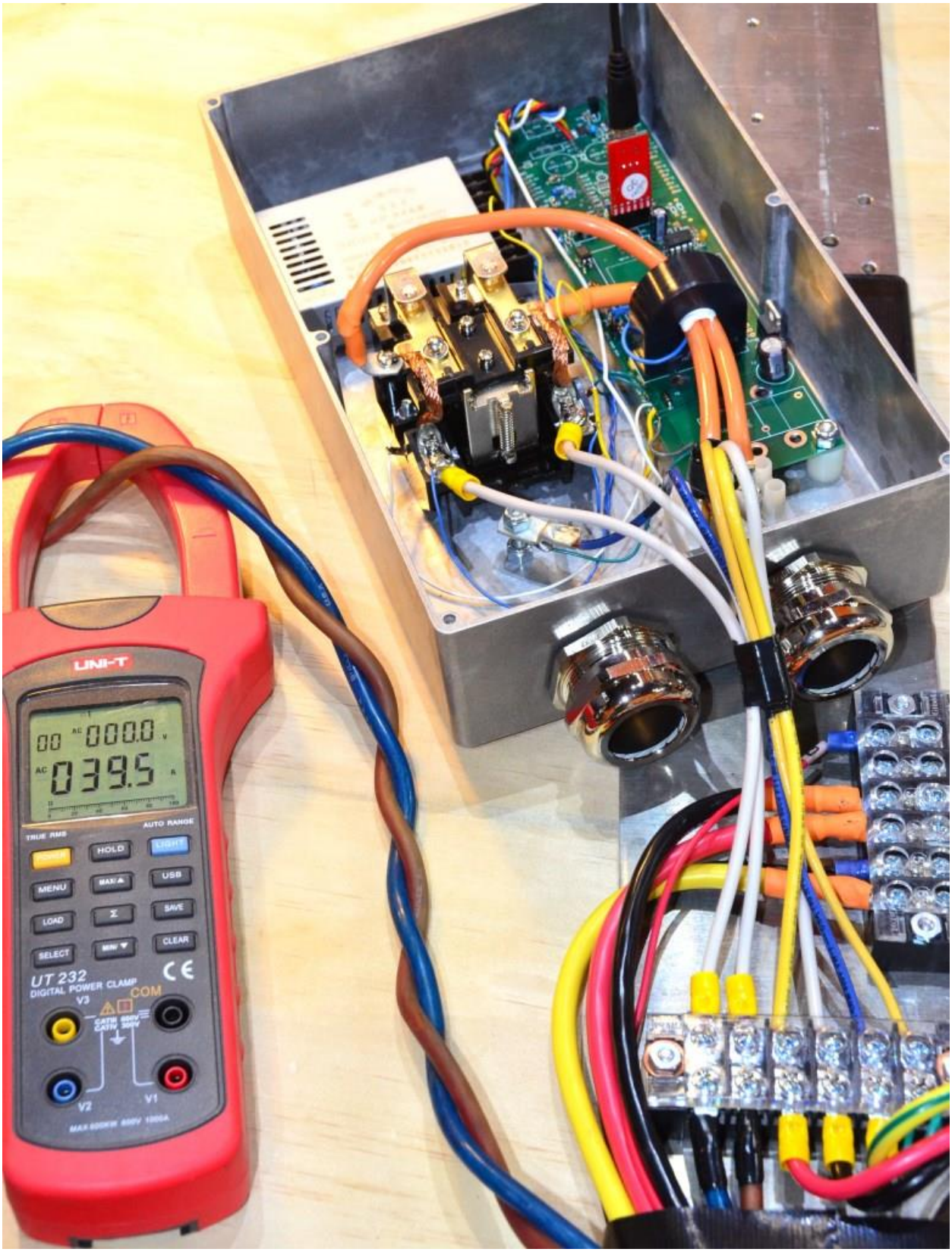
Sturdier.

More protected.

And you built it yourself!

Go Electric!

Yours truly,
EMW Power Electronics Crew



JuiceBox charging a 2013 RAV4 EV at 40A

All assembled units are tested on this car before they ship – both at 120V and 240V