Build your own ...

MOTHERBOX

(Open source GBGo-bot control module)

brought to you by the

wild-eyed, warranty-destroying funsters @ POP

Voiding Warranties
for a good cause
since 2014

mobility & sociability

GO
BaBy
go!

Rocky TOP

A "Power of Play" Project

Play with a Purpose

www.power-of-play.org

Introduction & Acknowledgements

Here at Go Baby Go-Rocky Top we've tried to build upon Dr. Cole Galloway's amazing original idea of turning toys into transportation for kids with mobility impairments. Our idea was to take it a step further, by designing a control module to allow switch input not only for forward propulsion but also to allow power steering, for those kiddos that lacked the strength or ROM to manipulate manual steering mechanisms. The dream team - comprising our own Larry Ward, OT extraordinaire, in collaboration with Blake Palmer from First Wheels Houston - was able to come up with the "Motherbox" control module, and it's been a real game changer for a lot of our kids.

The Motherbox (MB) is a **modular design**, such that it can be retrofitted onto any 6V or 12V, dual motor vehicle … allowing the potential for kids to have multiple vehicle options without excessive modifications required. It combines switch inputs for forward, left, right & reverse, along with speed control, motor balance control (to help adjust for "veer"), emergency stop capabilities (both hard-wired & remotely) with options for acceleration control (if desired) and "fun button" functionality (if required .. will explain in another document). The MB contains an Arduino Uno mother board, paired up with a Sabertooth dual motor controller, & runs via our "Fluid Motion Device" software. The benefits of modularity include allowing for situations like a child having a mid-wheel drive configuration vehicle (such as the Dareway, better suited for indoor mobility), as well as rear-wheel drive vehicle (such as a Power Wheels jeep, better suited for the great outdoors), & just transfer the control module & seating between them. More importantly, when / if problems arise, we can quickly swap one Motherbox for another, allowing for easier trouble-shooting and less downtime. It also allows the potential for switched joystick input, attendant control, & probably all sorts of stuff we've not even considered yet. Take it and run with it .. just be sure to share any good stuff you devise with the rest of us. Many candles just make the room brighter for all of us.

Many thanks to the talented, generous and crazy-brave individuals who helped design, field test, fund, & fine tune this ingenious idea – Blake Palmer (da man!! @ First Wheels Houston), Larry Ward (OT w a black belt in DIY electronics), Dr. Lois Symington (our "fairy godmother" who put a roof over our heads & wind beneath our wings), Bert Laws (GBG Music City … "hey why don't you guys put all that stuff in a box"), our own Margarita Mafia (Jess, Ali & Alex … you gals are the best), Jimmy (man with the knife) Clapp, Carol Fusco & the gang from Variety Children's Charity of East TN (your support made all this possible), Rod Reynolds ("Hey, you should write this stuff down") … and too many others to fit onto a page. Thanks also to the brave parents & kids that agreed to be our "guinea pigs" as we worked through the kinks on this project … your smiles make it all worth the effort. And lastly, my family, who put up with my crazy every day as I try to live up to Doc Galloway's challenge to do more. A famous man once said "My faith demands that I do whatever I can, wherever I am, whenever I can, for as long as I can, with whatever I have, to try to make a difference." Here at POP's "Go Baby Go – Rocky Top" project we're trying to do just that. Hope you will join us ;)

Ok, enough chit chat, let's get down to brass tacks, shall we?

Supplies Needed (see Appendix A – shopping list, for more details)

- Project box (we prefer to use a 8" x 5" x 3" black ABS box from Radio Shack)
- Arduino Uno Board
- Sabertooth 12V dual motor controller (from Dimension Engineering) – amperage rating per vehicle requirements. We usually use 32Amp version
- Screw Shield connector for Arduino Uno (we prefer this bc less soldering involved)
- Linear potentiometers x 2, with green & yellow knobs
- 3.5mm panel mount mono switch jacks (x5)
- On/off switch, rated DC 12V, 20+Amps, preferably w LED indicator
- Wire (14AWG, stranded) … red, black, white & blue spools
- Wire (22 AWG, stranded) … red, black, blue, green, yellow, brown, orange, white, grey & purple spools (just helps to visually identify which wire goes where easier)
- 2-conductor, waterproof connector (we use 14 AWG)
- Rolls of ¼" and 1/8" Heatshrink to cover any exposed metal on electrical connectors
- Butt connectors for 18-22AWG
- Butt connectors for 14-16AWG wire
- Bullet terminals .157" male & female for 14-16AWG wire
- Quick disconnect terminals, male & female .25", for 14-16AWG wire
- In-line fuse connector (amp rating depending on build)
- Spacers/standoffs for mounting Uno board and Sabertooth inside project box
- Push-in wire connectors (3-port)
- Faston T-shape connectors (available from Mouser.com)
- Fimco remote power stop (available from Tractor Supply)
- Zip ties
- Split flex tubing (to "tidy up" exposed wires)

Tools Needed

- Drill, with full set of drill bits
- Needle nose pliers
- Crimping tool
- Wire cutters & strippers (for wire 12-22AWG)
- Heat gun / hair dryer
- Computer w USB-B cable
- Soldering iron
- Set of small screwdrivers for working with electrical devices
- Flat head & phillips head screwdrivers, regular size
- Small handsaw for cutting plastic
- Hemostat clamp (very useful in tight spaces if you have fat fingers … like me)

MB Assembly

Once you've assembled your tools & supplies, and gathered your courage, it's time to roll your sleeves up & get down to some serious "maker-ing" ….
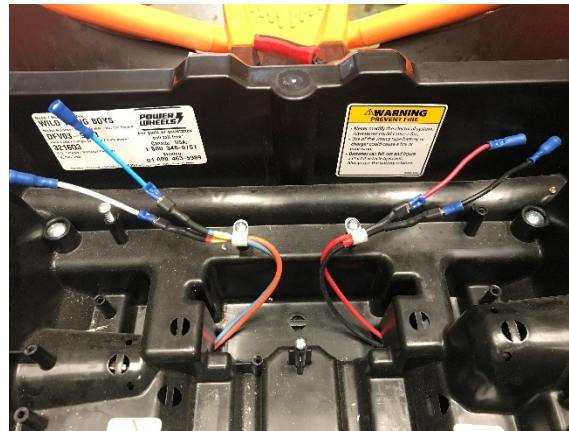
1. Project box prep

- We decided on the configuration we wanted, for where all the bits & pieces would fit into the project box, then made a number of templates so we wouldn't have to think so hard each time. I recommend you do the same.

- Make pilot holes in bottom of project box for mounting Uno board and Sabertooth. Also pilot hole for where you plan to "exit" wires out to vehicle.

- Make pilot holes in front of box for directional switch jacks, E-stop switch jack, on/off switch, speed potentiometer & motor balance potentiometer

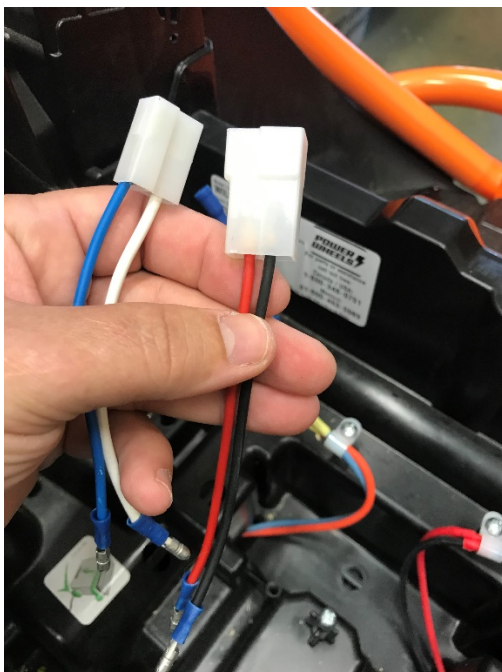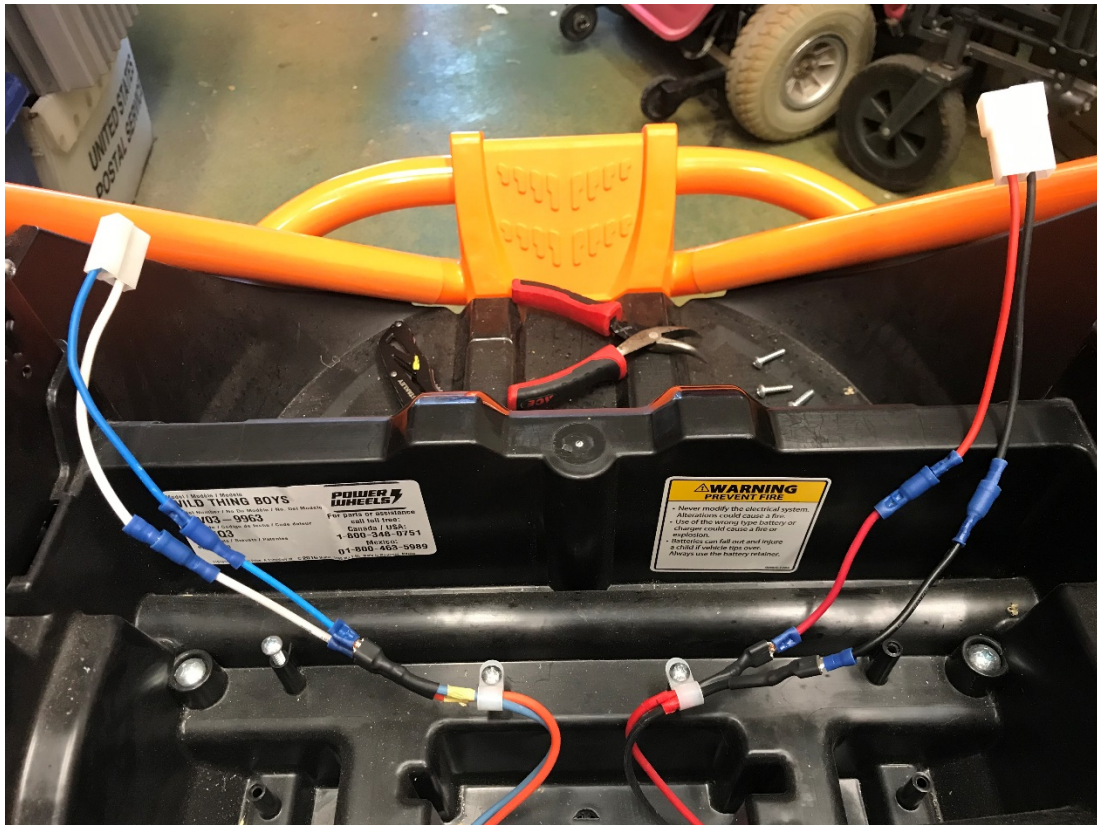- Make pilot hole on side of box for access to USB-B port on Uno board

2. Vehicle Prep

- In all builds whenever possible, try to preserve the OEM connectors (in case you ever want to reconfigure Wild Thing / other vehicle back to OEM design)

- For a Wild Thing build, let's first disconnect the motor connectors from the circuit board, & cover exposed metal with heatshrink.

- We then make an "adapter" hookup, using a 1/4" male quick-disconnect terminal inserted into the existing motor lead's female terminal. Crimp male terminal to approx. 3-4" of 14AWG wire, preferably matching colors. Then crimp a female bullet terminal to the end. Repeat for all four motor leads.

- As part of our modular concept, and to hopefully avoid anyone connecting motor or power supply lines incorrectly, we prefer to use "Fast-On" polarized connectors. For consistency, on the vehicle side, we use a female connector for the left motor and a male connector for the right. these attach to the existing set-up via male-end, bullet connectors.

- Now onto the battery connector. You will need to identify positive and negative power lines from battery, in order to reroute power to Motherbox. This can be accomplished using a multimeter, while also measuring voltage output.

- Depending on vehicle type, consideration may need to be given to the battery charging system used (eg Power Wheels type removeable battery vs non-removeable, onboard charger and battery of other manufacturers).

- As an example, for this Power Wheels "Wild Thing" set up, and keeping in mind the distance between battery placement and potential MB placement ... disconnect wires from circuit board, then cover exposed metal using heatshrink.

3. Wiring Harness Assembly

There are 3 main wiring harnesses to assemble …
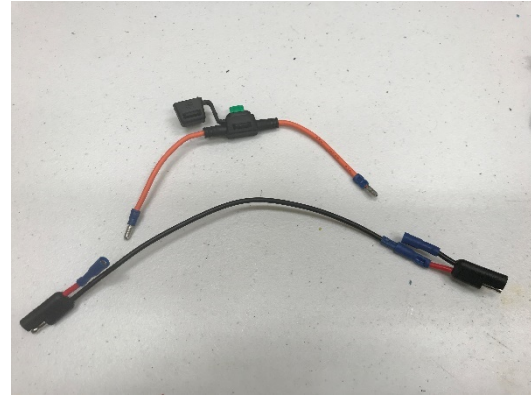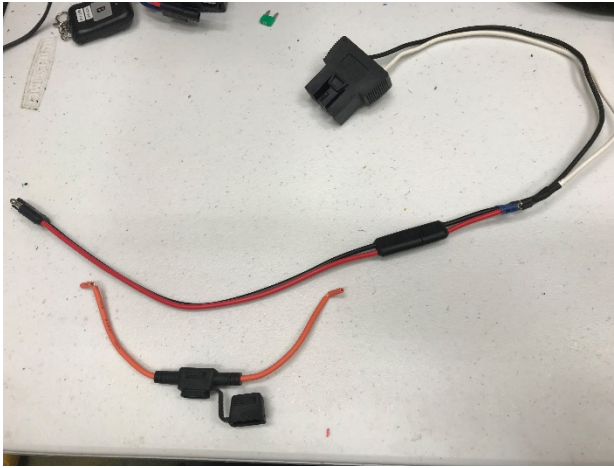
A. Power "Supply" wiring harness

- This wiring harness will basically conduct power from the vehicle battery to the Motherbox. Modifications on the vehicle-side will vary depending on the vehicle, but will ultimately end up connecting to a 2-conductor, waterproof connector.

- On the MB side of this wiring harness, we will be connecting our in-line blade fuse circuit breaker, then the Fimco Remote Stop system. These connect to the waterproof connector that protrudes from MB.
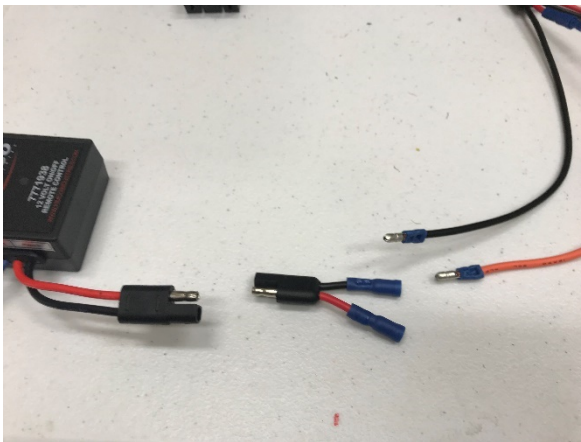

- Now cut one of the 2-conductor waterproof harnesses about 3-4" from one end. Save the longer end for later. Crimp ¼" male "slide" connectors to red and black wires of the shorter end. These will insert into the existing female OEM connectors on the battery harness (again, trying to preserve original connectors)
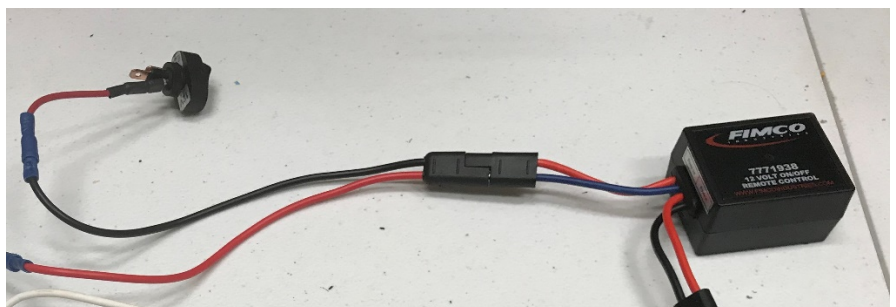
- Next we will be connecting our **in-line blade fuse circuit breaker**. We accomplish this by basically replacing the red (positive) wire on one of our 2-conductor waterproof harnesses. We use male and female bullet connectors to do this, so that we can easily replace this part if necessary.

- Next comes the **FIMCO remote stop**. It already has it's own 2-conductor waterproof connectors, which should make it easy enough ... except you may have to traumatize your engineer friends by reversing the connector ends in order to fit the FIMCO. Just be sure to label whichever wire is carrying the positive current and it will be fine.
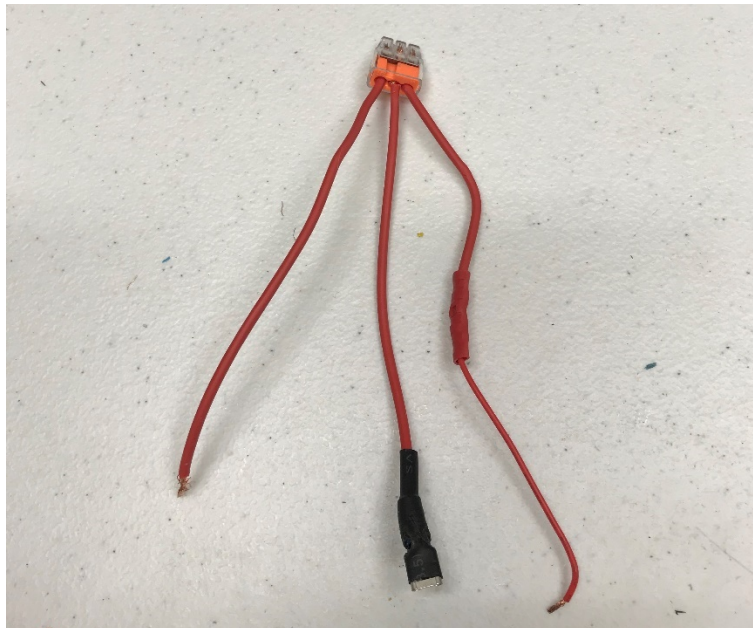
- The last connection on the supply harness will be the longer remnant from the 2-conductor wire you cut earlier. It will connect to the FIMCO on the "power out" side. Then crimp two male "bullet" connectors to the ends. Take another 3-4" length of 14AWG red wire and crimp a female bullet connector on one end (to connect to FIMCO side) and a female ¼" quick connect on the other (to connect to supply male terminal on on/off switch)
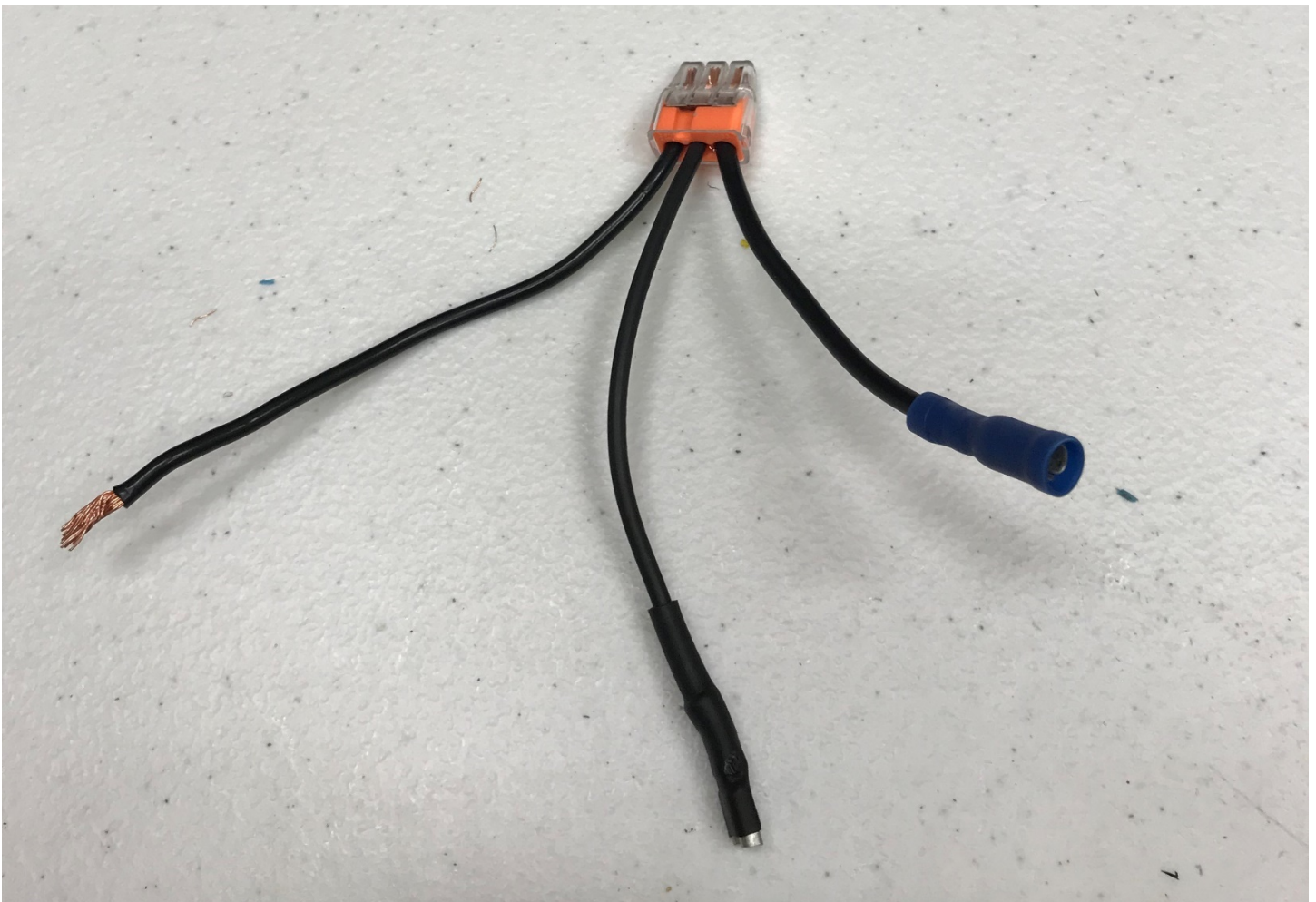
B. Red "Load" wiring harness

- This wiring harness connects between the Load terminal on the on/off switch, the B+ input terminal on the Sabertooth, and the V-in terminal on the Arduino / Screwshield

- Cut two 4-5" lengths of red 14 AWG wire, & one 2-3" length

- Remove 1/2" of plastic sheathing from each wire, then insert the wires into a 3-hole push-in connector.

- Remove 3/8" of sheath from one of the 4-5" wires, then crimp on a blue female ¼" quick disconnect terminal. Cut & apply heatshrink. This will eventually attach to the male Load terminal on the on/off switch, but not yet.

- Trim ¼" of sheath from the other 4-5" length. This will eventually plug into the B+ terminal on the Sabertooth … but not yet!

- Trim 3/8" of sheath from the 2-3" length, twist the exposed wire, then crimp on a red 18-22 AWG butt connector. Cut a 3-4" length of red 22 AWG wire, then trim 3/4" of sheathing from one end. Fold the exposed wire in half, then twist the halves together (this effectively doubles the wire diameter & helps make a better crimp attachement). Insert twisted red 22AWG wire into other end of 18-22 butt connector & crimp. Trim ¼" of sheath from the other end of red 22 AWG wire. This will eventually plug into V-in terminal on the Screwshield, but not yet.

C. Black "Earth" wiring harness

- This wiring harness connects the Earth terminal on the on/off switch (assuming you're following our advice & using a switch with an LED light), the B- terminal on the Sabertooth, and the wire running from the protruding 2-conductor, waterproof connector.

- Cut three 3-4" lengths of black 4AWG wire. Trim ½" of sheathing from all three, & insert into a 3-hole push-in connector.

- Remove 3/8" of sheath from one wire, then attach a blue 14-16AWG female quick disconnect terminal. Crimp & apply heatshrink. This will eventually attach to the male Earth terminal on the on/off switch, but not yet.

- Remove 3/8" of sheath from the next wire, then add a blue 14-16AWG bullet terminal (female end) & crimp. This will eventually lead back to the negative power line (on the supply harness) to the vehicle battery, but not yet.

- Remove ¼" of sheath from the last wire. This will eventually plug into the B- terminal on the Sabertooth … but not yet.

4. Soldering, soldering, & more soldering = Screwshield Prep

Time to assemble all the little fiddly bits that provide input to the Motherbox. First up …

A. Switch jack for **Forward** input
   - Cut a 4" length of **green** 22 AWG wire, & a 4" length of black 22 AWG
   - Remove ¼" length of sheath from both ends of both wires
   - Solder one end of green wire to projection on 3.5mm mono jack closest to threaded end.
   - Solder one end of black wire to the projection furthest away

   - Twist exposed wire at other end of green length, and insert into terminal **A3** on the Screwshield
   - Twist exposed wire at other end of black length, in preparation to attach to "the spider" (all will be explained)

B. Switch jack for **Reverse** input
   - Cut a 4" length of **blue** 22 AWG wire, & a 4" length of black 22 AWG
   - Repeat steps as for Forward input, except other end of blue wire inserts into Screwshield at terminal **A4**

C. Switch jack for **Left** input
   - Repeat steps as above, except this time use **yellow** 22 AWG wire, and insert into Screwshield at terminal **A5**
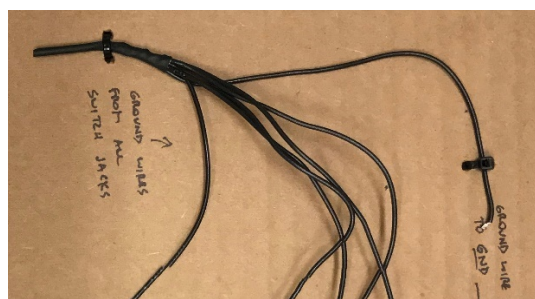
D. Switch jack for **Right** input
   - Repeat steps as above, except this time use **red** 22 AWG wire, and insert into Screwshield at terminal **A6**

E. Switch jack for **Emergency Stop**
   - Repeat steps as above, except this time use **brown** 22 AWG wire, and insert into Screwshield at terminal **A2**

F. **The "Spider"** (named by our volunteers .. who am I to argue?)
   - Because there is limited space in the ground terminal on the screwshield, we take all the black wires and solder them together, along with one more black wire which will attach to the "GND" terminal.
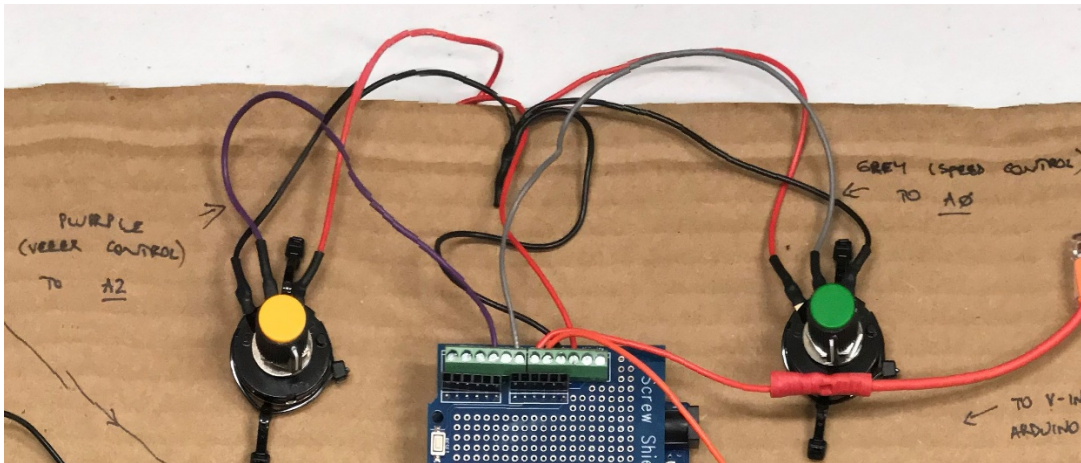
G. **Speed Potentiometer**
- Cut 5" lengths of red, black, & grey 22 AWG wires
- Trim ¼" of sheath from both ends of each wire.
- Solder **black wire to terminal 1** of potentiometer, & then make a mini-"Spider" using the loose black wires from both potentiometers, attached to a third black wire, which should now insert and fit into **GND** terminal (next to 5V)
- Solder **grey wire to terminal 2** of pot, insert other end into **A0** terminal
- Solder **red wire to terminal 3** of pot, & then make a mini-"Spider" using the loose red wires from both potentiometers, attached to a third red wire, which should now insert and fit into the **5V** terminal
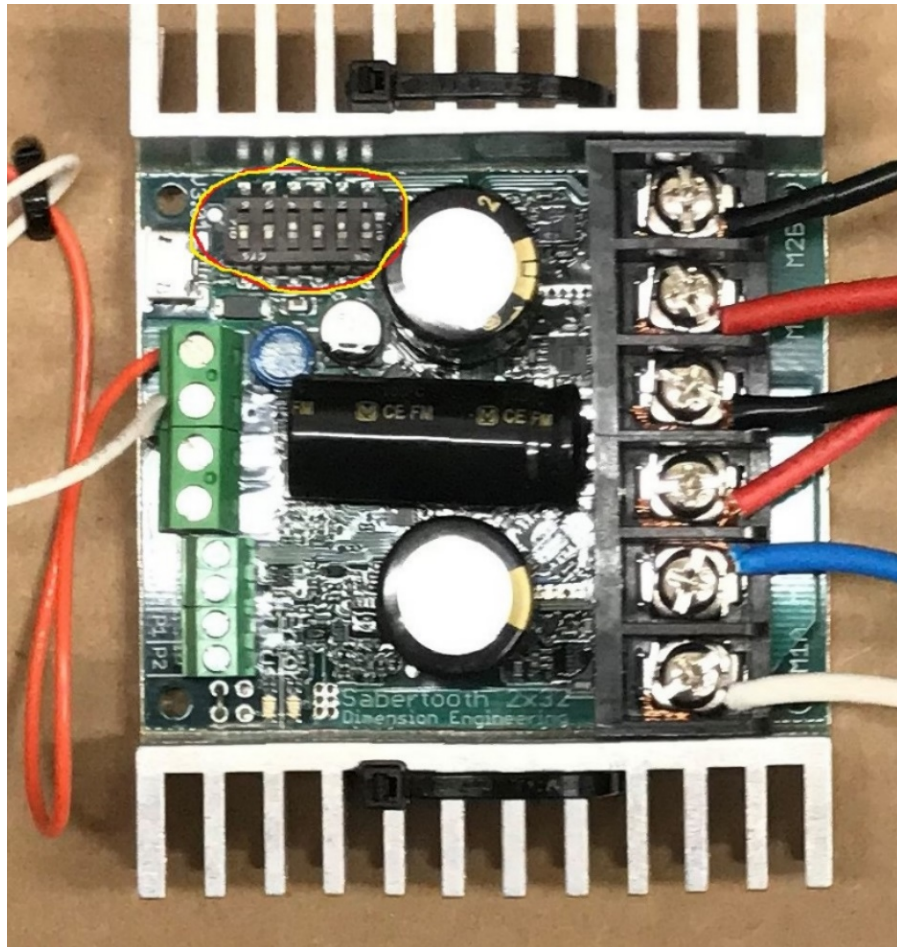- Attach green knob to pot shaft using set screw

H. **Motor Balance / "Veer" Potentiometer**
- Cut 5" lengths of red, black & purple 22 AWG wires.
- Trim & solder as above, except **purple wire inserts into terminal A2**.
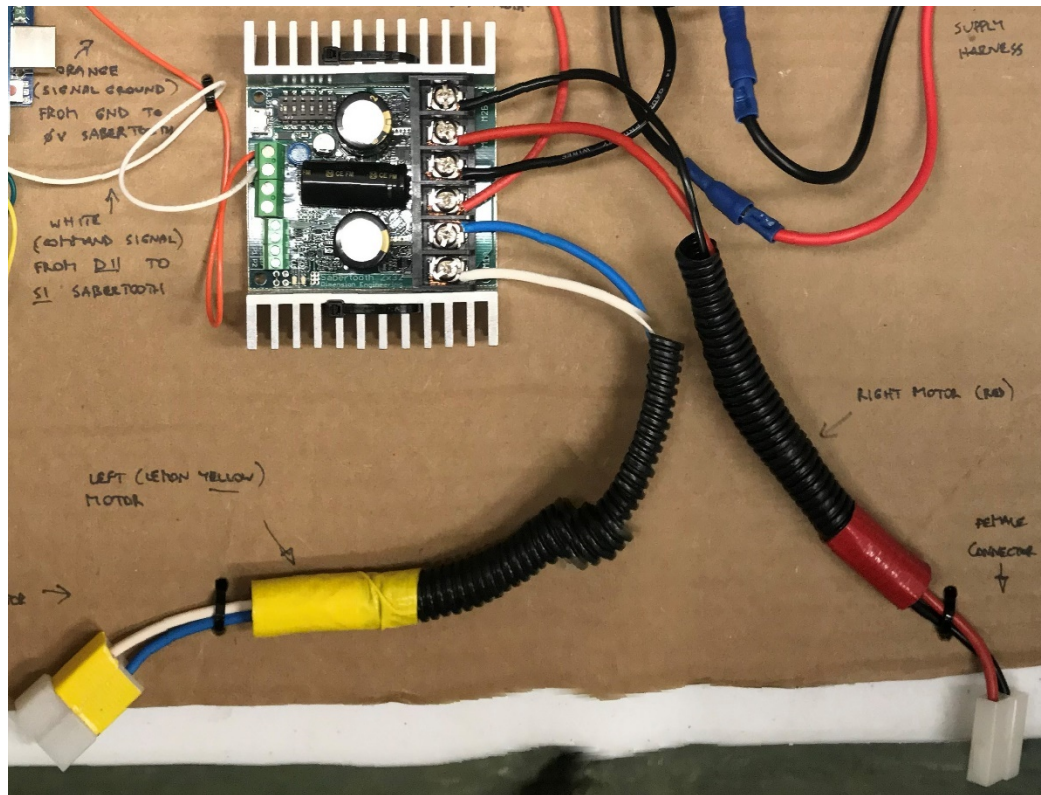- Attach yellow knob to pot shaft using set screw.

5. Sabertooth Motor Controller Prep

- Ensure dip switches on Sabertooth are set per picture below (position changes depending on software being used & it's requirements)

- You may need to determine the size (AWG) and polarity (which wire positive, which negative) of the wires coming out from the motors. Size should be printed on the wire sheath. Polarity can be determined by applying a 12V current to the motor wires (using suitable / safe connector or test leads) & noting which configuration causes them to rotate forwards.

- Positive wires to the motors will attach to the Sabertooth at positions 1 and 6.

- Negative wires from the motors will attach to the Sabertooth at positions 2 and 5.

- Using 14 AWG wire & trying to match the colors of the motor leads coming from left & right motors, prepare your motor connections using T-junction Faston connectors. For the sake of uniformity, we use the **"receptacle" (female connector) for the "right"** motor leads coming out of the Sabertooth at positions 5 and 6. Then use the "tab" (male) connector for the left motor leads coming out of the Sabertooth at positions 1 and 2.

- Cut a 4-5" length of **white** 22 AWG wire, strip ¼" from both ends, & attach one end to **D11** terminal on Uno & other to **S1** on Sabertooth.

- Cut a 4-5" length of **orange** 22 AWG wire, strip ¼" from both ends, & attach one end to **GND** terminal next to VIN on Uno, and other end to **0V** terminal on S'tooth.
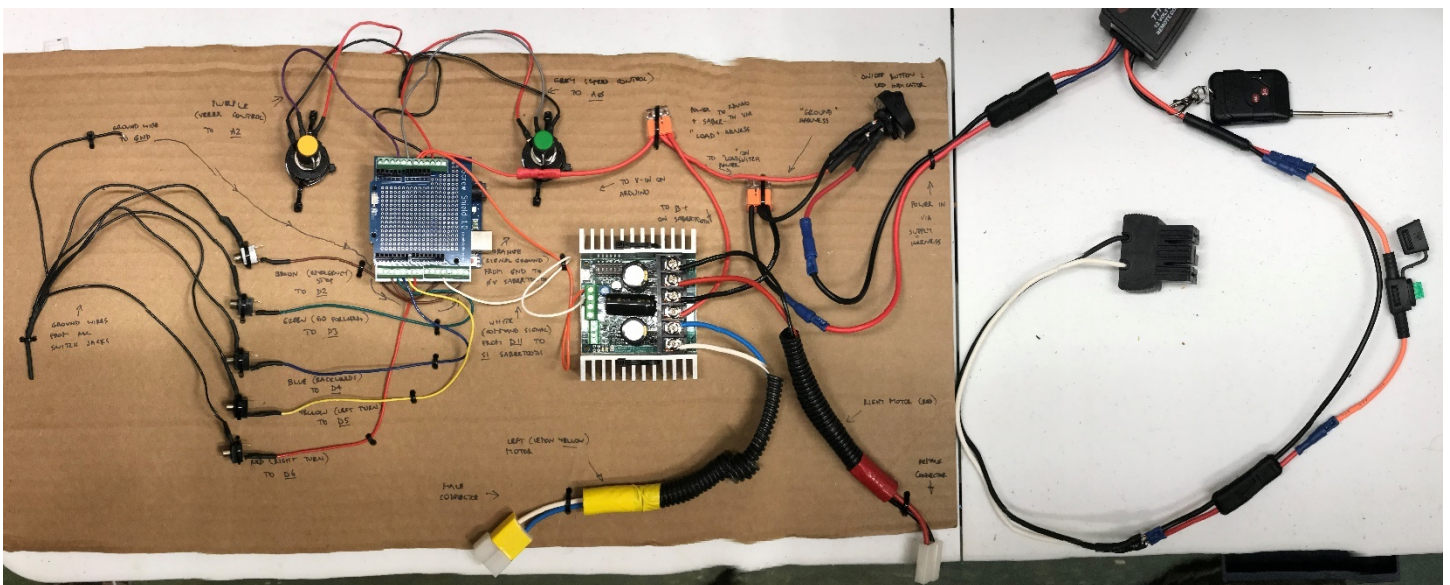
6. Arduino Uno Prep

- Connect Arduino to computer source via USB-B cable
- Upload "Fluid Motion Device" software to Arduino (refer to internet for instructions)

7. Test Run – "The Rack"

At this point, I would recommend plugging everything in & making sure it all works before tucking it all nicely into the project box & finding out it doesn't!! So that entails …

- Attach Load, Supply & Earth power harnesses to respective terminals of on/off switch
- Attach red wire from Load harness to B+ terminal on Sabertooth
- Attach black wire from Earth harness to B- terminal on Sabertooth.
- Attach red 22 AWG wire from Load harness to VIN terminal on Uno
- Now find a flat surface you can spread the whole assembly out on, so you can visualize all components.
- Give a gentle tug to all screwshield connections to make sure they're secure.
- Visually inspect all power connections and use heatshrink or electrical tape to cover any "shiny" surfaces, to reduce risk of short-circuiting.
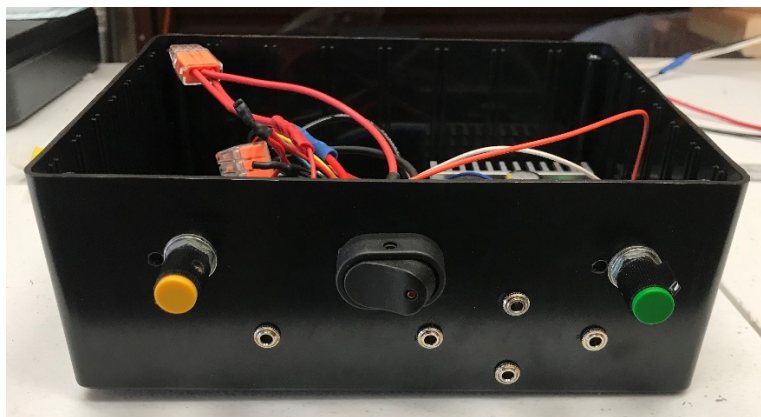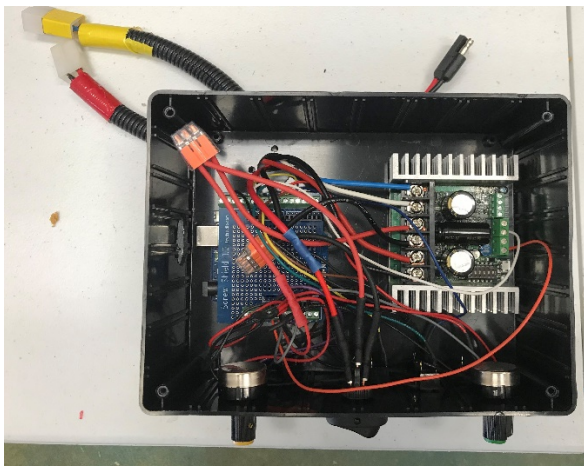

- Connect motor leads, then power to battery.
- If using a FIMCO remote stop, you will need to push the "on" button on the fob.
- Then switch on MB on/off switch. LED indicator should light up.
- Allow 1-3 seconds for Arduino CPU bootup, & ensure power lights on Uno, Sabertooth, & on/off switch indicate power supply.
- Plug a switch into each "directional" monojack input & check for motor control
- Plug a second switch into the emergency stop jack. While motors are running, activate this switch to ensure functionality of this feature.
- Similarly, while motors running, depress the "off" button on the FIMCO unit to ensure functionality.
- Test speed potentiometer for effect.
- Test motor balance potentiometer for effect.
- Trouble shoot as / when needed. (see appendix for FAQs)

8. Final Assembly

If everything performed as expected during test run, or minor glitches have been resolved, now it's time to box this bad boy up …

- Attach Uno board to interior of project box using 10mm standoff inserts. Ensure access to USB-B port
- Attach screwshield to Uno board, then attach all its components in their respective places (mono jacks, potentiometers)
- Attach on/off switch to project box, then connect Load, & Earth wiring harnesses accordingly.
- Attach Sabertooth enclosure to project box, & run motor connector wires through whatever "wire outlet hole" you've made, and connect then to Sabertooth.
- Similarly, run Supply line wires through the wire outlet you've made. At this point, you should have something resembling this ....

- Once assembled, time for another safety / quality control check.

9. Safety Check

Everything was working before you boxed it up. Now it's time to make sure you didn't knock anything loose during final assembly.

- Visually inspect all connections (especially those in close proximity, which in this case is virtually all of them) to make sure no chance of short circuiting. Move stuff around / re-solder / apply heatshrink or electrical tape as necessary. No wires touching that shouldn't be!! No shiny metal exposed on electrical connections that shouldn't be!!

- Give a gentle'ish tug on your crimped connections to make sure they're solid

- Plug Motherbox into a vehicle (preferably the vehicle you plan to use) & run it for at least 30 minutes, then check for heat buildup. If you're not sure, or you think there's maybe a problem, trust your gut & have an engineer check your work (if you haven't already)

Better safe than sorry … always!!

- Make sure emergency stop function is working, both the hardwired version and the FIMCO if used.

In fact, work **really hard** to find an engineer with a heart of gold who will work alongside you to make sure everything's as safe and sound as possible. You'll probably sleep better … especially if they start talking engineering-stuff. Just kidding ;)

10. Troubleshooting

"Learning Opportunity"	Possible Solution
MB is powered up but motors won't move when I push button?	Give the MB a second or two to "boot up" when you first turn it on before trying input via buttons. Make sure the input switch you're using is functional. Then try plugging it into a different jack to see if that's the issue. Also, make sure speed potentiometer is at least turned ¼ way around, otherwise not enough power going to motors to turn them
On/off switch LED light is on, Sabertooth light is on, but Arduino board light not on.	The on/off LED receives power directly from battery. The Sabertooth receives power via red Load harness. But power for the Arduino passes through the Screwshield, & sometimes the Vin terminal has been faulty. Use a continuity tester to check it out.
When I plug Arduino board into laptop via USB-B cable my laptop can't "find" the Arduino?	We've had at least one Arduino board where the communication "chip" that runs between the USB & the Arduino "brain" was faulty. Try a different Arduino board. And label which one you think is faulty … they all look the same so easy to mix'em up. Also, if the Uno board is already built into a MB unit, make sure the MB on/off switch is on.
When I turn the speed up, the go-bot actually slows down?	If you accidentally get the red & black wires reversed when soldering to the potentiometers, it reverses their direction of control.
When I turn the MB on, nothing happens? No lights … nada!	Use a voltmeter/multimeter to check the battery & make sure at least 12V available. Make sure battery terminals are connected. Check all crimped connections. If FIMCO light on but on/off LED on MB not lit, make sure you've pressed "on" on FIMCO fob.

Appendix A ... The Shopping List

Here's links to the places we mostly buy the supplies we need. If you find something better, or cheaper, or better suits your needs, that still gets the job done … more power to you. Just don't forget to share pls. This will always be a work in progress, because there's always more to learn :)

* RadioShack 8" x 6" x 3" ABS project box …. https://www.amazon.com/RadioShack-Project-Enclosure-Box-inches/dp/B001U7OUEY

* Arduino Uno board … https://www.arduino.cc/en/Main/ArduinoBoardUno

* Sabertooth Motor Controller ... https://www.dimensionengineering.com/products/sabertooth2x32

* Screwshield connector for Uno board … https://www.robotshop.com/en/cytron-screw-terminal-shield-arduino.html

* FIMCO 12V remote stop ... https://www.tractorsupply.com/tsc/product/fimco-12-volt-wireless-remote-on-off-switch

* In-line fuse holder ... https://shop.advanceautoparts.com/p/littelfuse-heavy-duty-ato-fuseholder-with-cover-card-fhac0002xp/11694393-P?navigationPath=L1*14920%7CL2*15004%7CL3*15640

* Linear potentiometers to control speed & motor balance … Link to potentiometers at AllElectronics.com

* Pointer knob, green, for speed potentiometer ... http://www.allelectronics.com/make-a-store/item/knb-267gn/pointer-knob-for-6mm-shaft-green-face/1.html

* Pointer knob, yellow, for motor balance potentiometer ... http://www.allelectronics.com/make-a-store/item/knb-267yl/pointer-knob-for-6mm-shaft-yellow-face/1.html

* 3.5mm mono switch jacks ... http://www.allelectronics.com/make-a-store/item/mmj/3.5mm-mono-open-audio-phone-jack/1.html?extra=a%3A2%3A%7Bi%3A0%3Bs%3A40%3A%2203823345592a403b2f4a37a59384e7ab28f02be1%22%3Bi%3A1%3BN%3B%7D

* 12V "rocker style" on/off switch with LED … https://www.allelectronics.com/item/lrs-30r/12v-rocker-switch-w/red-led/1.html

* Spools of 14 AWG stranded wire ... red, blue, black & white … https://www.oreillyauto.com/shop/b/lighting---electrical/primary-wire/63b75c26df03?q=primary+wire&prodAttr_13710_ss=14+Gauge

* Spools of 22 AWG stranded wire ... red, black, blue, yellow, green, grey, purple, brown, orange & white … https://www.nteinc.com/wire/300.php#22gauge

* 2-conductor, waterproof connector 14AWG ... https://www.allelectronics.com/item/con-319/2-conductor-weather-resistant-connector-14awg/1.html

* Heat Shrink tubing 1/4" diameter ... https://www.oreillyauto.com/detail/c/dorman-conduct-tite/lighting---electrical/heat-shrink-sleeve-tubing/8e46691c474e/dorman-conduct-tite-heat-shrink-tubing/cti0/85266?q=heat+shrink+sleeve%2Ftubing&pos=5

*   Butt connectors for 18-22 AWG … https://www.oreillyauto.com/detail/c/dorman-conduct-tite/dorman-conduct-tite-butt-connectors/cti0/85435?q=butt+connectors&pos=2

*   Bullet terminal connectors .157" for 14-16 AWG ... https://www.oreillyauto.com/detail/c/dorman-conduct-tite/dorman-conduct-tite-male-female-bullet-terminal-sets/cti0/85429?q=bullet+terminals&pos=7

*   Butt connectors for 14-16 AWG ... https://www.oreillyauto.com/detail/c/dorman-conduct-tite/dorman-conduct-tite-butt-connectors/cti0/85436?q=butt+connectors&pos=3

*   Quick Disconnect / Slide terminal, female end, .25", for 14-16 AWG ... https://www.oreillyauto.com/detail/c/dorman-conduct-tite/dorman-conduct-tite-terminal-connectors/cti0/85452?q=quick+disconnect+terminal&pos=6

* Quick Disconnect / Slide terminal, male end, .25" for 14-16 AWG ... https://www.oreillyauto.com/detail/c/dorman-conduct-tite/dorman-conduct-tite-connectors/cti0/85453?q=quick+disconnect+terminal&pos=33

*   "Push In" style wire connectors … https://www.lowes.com/pd/IDEAL-In-Sure-Push-In-100-Pack-Orange-Push-In-Wire-Connectors/50101798

*   Faston 250 series T-connectors from Mouser electronics ... http://www.mouser.com/TE-Connectivity/Terminals/Fastin-Faston-Series/_/N-1yzs6iiZ5g5uZ1yzms1c