AR4 ROBOT BUILD

PROJECT 1 – EML6805

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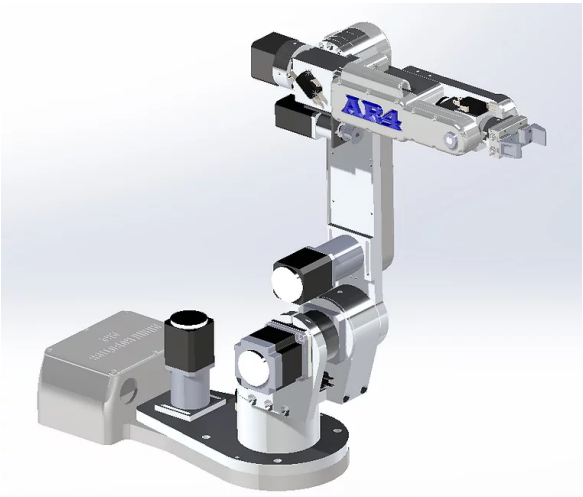
This will part one of two project reports for EML6805's new platform assignment. This document will provide a detailed explanation of elements of the AR4 robotic arm, assembly, and calibration.

DESCRIPTION

The AR4 robot arm is a six-axis robot designed by Annin Robotics. [www.anninrobotics.com] It aims to be a relatively inexpensive industrial grade arm platform for hobbyists, education, and small businesses. The design is only licensed for these uses, it is forbidden to produce or sell parts or complete robots derived from this design.



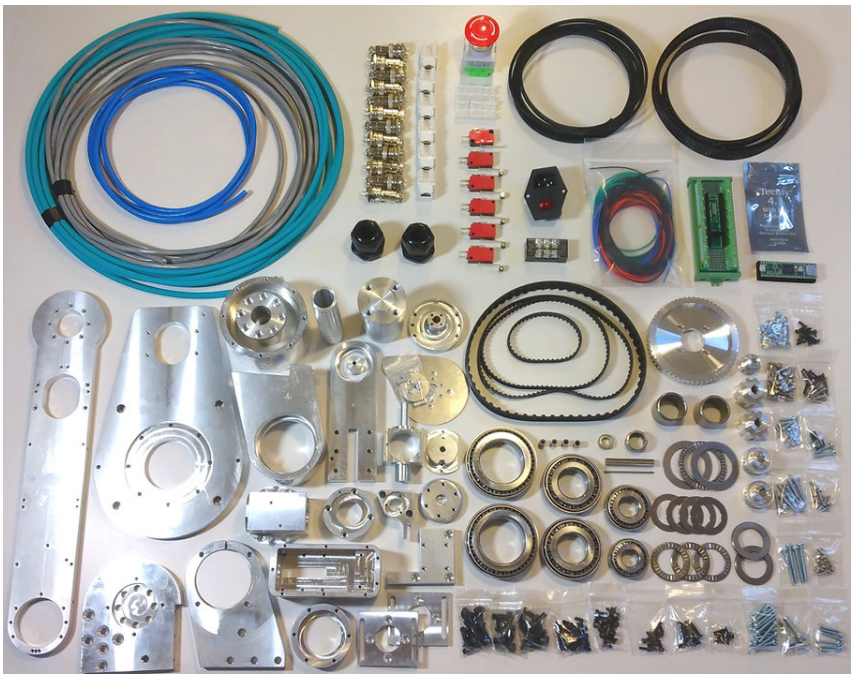
Source: Annin Robotics AR4 Build Manual

The AR4 is the fourth generation of the AR series robots. It includes a closed loop system with encoders built into the stepper motors as well as a 600MHz Teensy single board computer for on-board kinematics. The specification of this robot indicates that it expects to be able to deliver a 4lb payload with a repeatability of 0.2mm with a reach of 24.75 inches. [1]

COMPONENTS

COMPLETE COMBO KIT

To aid in completing this project in a timely manner the complete kit was ordered from www.anninrobotics.com for $1,189.00. This kit contains all the machined aluminum structural components, belts, bearings, single board computer, and all necessary wires/connectors.



Source: https://www.anninrobotics.com/robot-kits

- 26 Machined Aluminum pieces
    - Provide structural support and main links for robot
- 12 Bearings
    - Taper roller bearings that must be pressed into aluminum joints
    - Thrust bearings and needle roller bearings
- 6 Limit Switches
    - Each stepper motor has its own switch to ensure no over rotation and provides a zero point for encoder calibration
- 3.2m 20awg wires x 4 colors
    - Extending motor wires
- 6.6m Cat6 cable 26awg shielded
    - Extending motor encoders, and limit switches
- 9.15m 18awg 4 conductor cable
    - Wiring between robot and control enclosure
- Various screws, cable ties, belts, pulleys
- Teensy 4.1 – Single Board Computer
    - 600MHz CPU provides kinematics and motor control
    - Communicates to laptop computer through USB serial interface.

AR4 ROBOT COMPLETE ELECTRIC PACKAGE

Stepper Online has a package that includes all the stepper motors and power supply needed. The source of origin is China so take care of shipping times. My package arrived in 10 business days from order date. Total cost $616.66.

Source: https://www.omc-stepperonline.com/ar4-robot-complete-electric-package-stepper-motor-driver-and-power-supply-ar4/

- Joint 1: 17HS15-1684D-HG10-AR4
- Joint 2: 23HS22-2804D-HG50-AR4
- Joint 3: 17HS15-1684D-HG50-AR4
    - Note this motor is DIFFERENT than Joint 1's
- Joint 4: 11HS20-0674D-PG14-AR4
- Joint 5: 17LS19-1684E-200G-AR4
- Joint 6: 14HS11-1004D-PG19-AR4
- Nema 11 Bracket: ST-M3
- 5x Stepper Driver: DM320T
    - These provide power and signal management to the steppers from the Teensy
- Stepper Driver: DM542T
- Power Supply: S-250-24

ENCLOSURE & 3D PRINTED PARTS

The main enclosure houses all the stepper motor drivers, power supply, Teensy single board computer as well as all wiring is a BUD Industries NBF-32026. Also, an internal panel is used to attach components to the bottom of the enclosure. I ordered this from www.digikey.com including shipping and tax these components were ~$75.00.

Source: Annin Robotics AR4 Build Manual

The 3D printed parts are printed at the Sea3D UWF facility. The parts that can be, will be printed in carbon fiber for its heat

resistance. I plan to use this robot to do some welding and plasma torch cutting. ~$300 USD for carbon fiber printing.

ASSEMBLY

The assembly of the robotic arm and the wiring of the enclosure was a lengthy process. Originally estimated to only take about 25 hours, it took over 50 hours. Some of this was due to mistakes but building anything the first time requires patience.

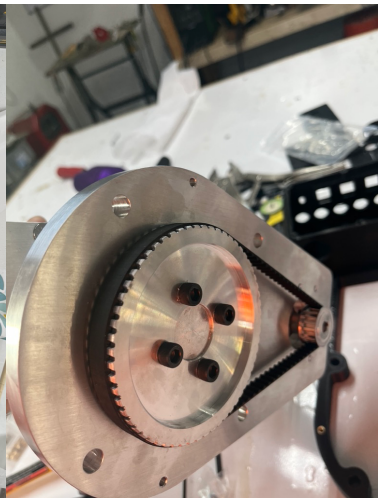
TOOLS REQUIRED

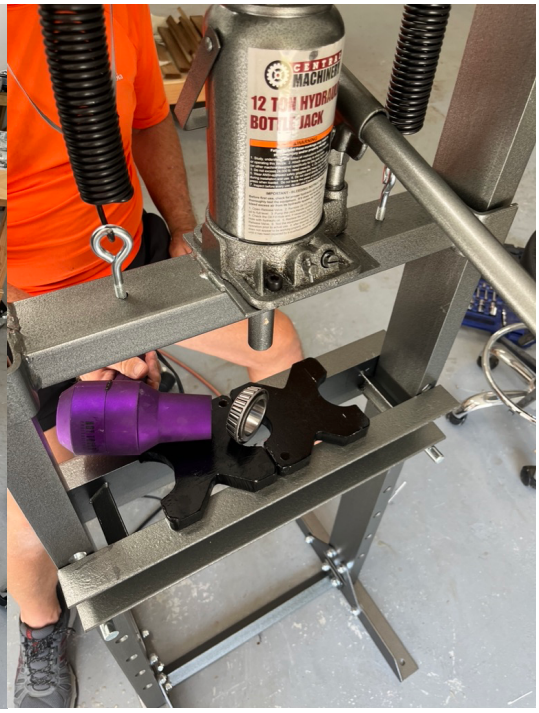
- Shop Press for pressing in bearings into aluminum components
- Soldering Iron – Solder, Flux, 62/36/2 Silver Bearing Solder
- Wire Strippers

- Razor Blades
- Various Metric Allen Wrenches
- Heat Gun
- Electric Drill - Counter Sink Bits, Various drill bits
- Network Punch
- Multimeter
- Oscillating Saw





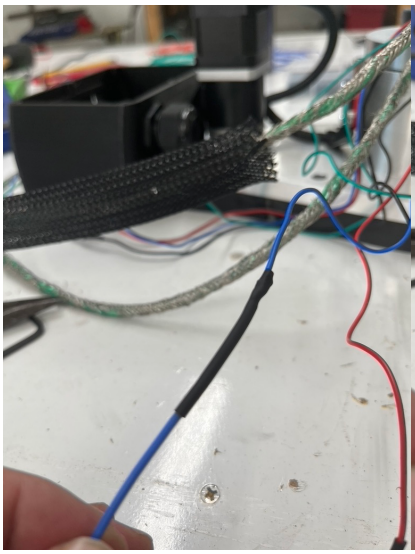


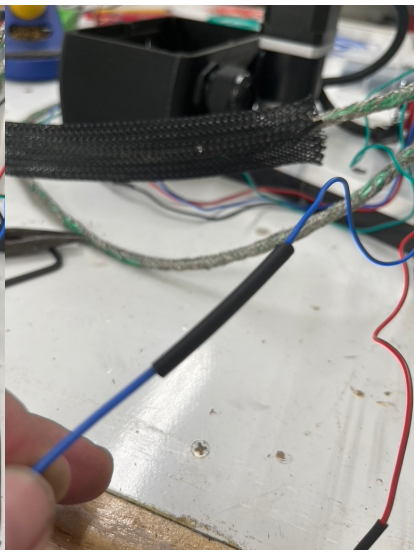


ROBOT ASSEMBLY

Following the build manual, we start with applying epoxy two base components. The parts that are milled out of aluminum are supposed to be a light press fit. Polishing of the components or heating & cooling were required for most of the joints. Also, the shop press was mandatory for some of the bearings to be pressed in exactly the right orientation.

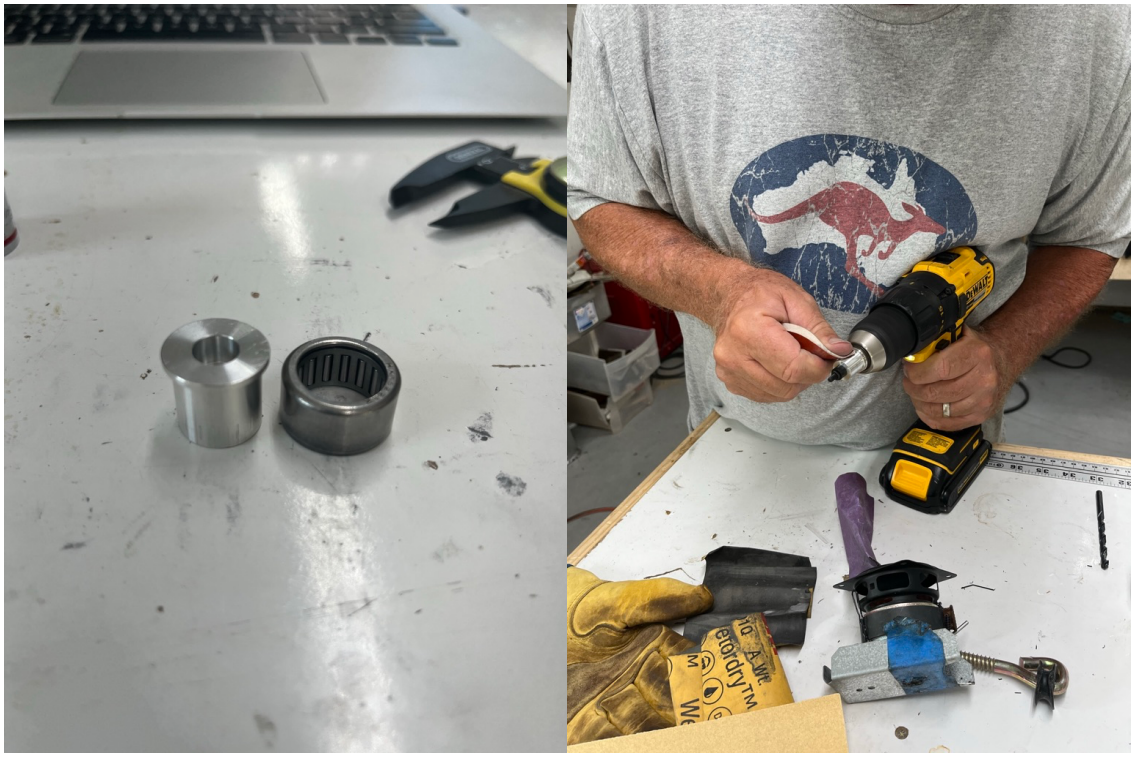
The assembly process follows from Joint 1 (J1) to Joint 6 (J6). At each joint a bearing and motor are pressed into the aluminum pieces and the wires are extended and connected to the encoder and limit switch. Heat shrink tubing is applied on all soldered joints.



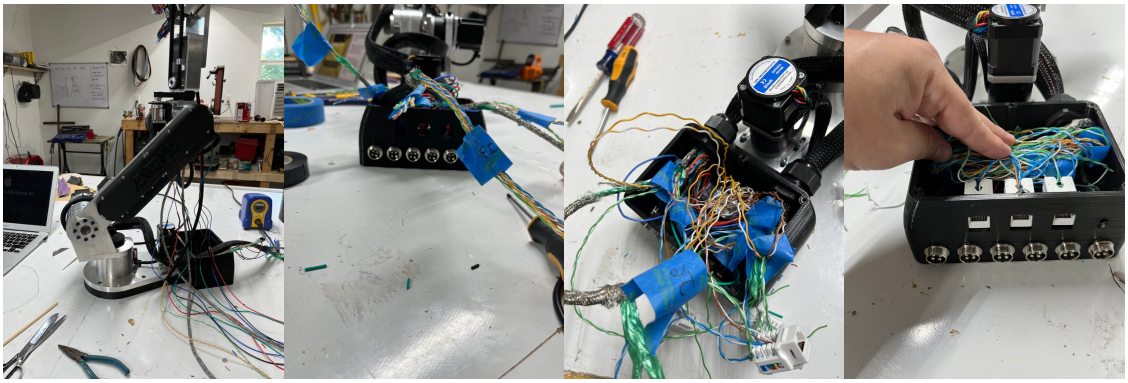


Note that the J2 ARM is not a symmetrical piece. In the above picture the entire arm was pressed onto the bearings backwards. This cost a significant amount of rework and clever use of various sockets and the shop press. Two people were required to hold robot and operate the press while undoing the mistake.

The needle bearing and the J5 bearing post were at the edges of each of their tolerance and a press could not be established without first polishing the post.



At each stage of the motor assembly each joint was checked for articulation and cables were routed through braided sleave making sure to label which joint it was coming from.

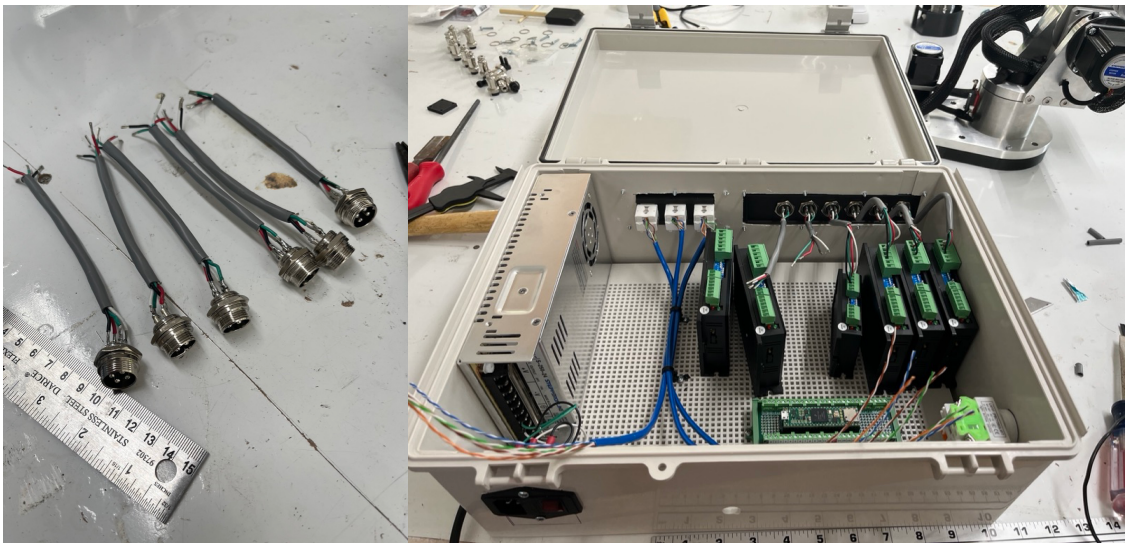


ENCLOSURE ASSEMBLY & WIRING

Once the robot was completely assembled the enclosure must be completed. The enclosure holds all the stepper drivers, power supply and the Teensy single board computer.

The enclosure must first measured and marked for the connector panels that were 3d printed.

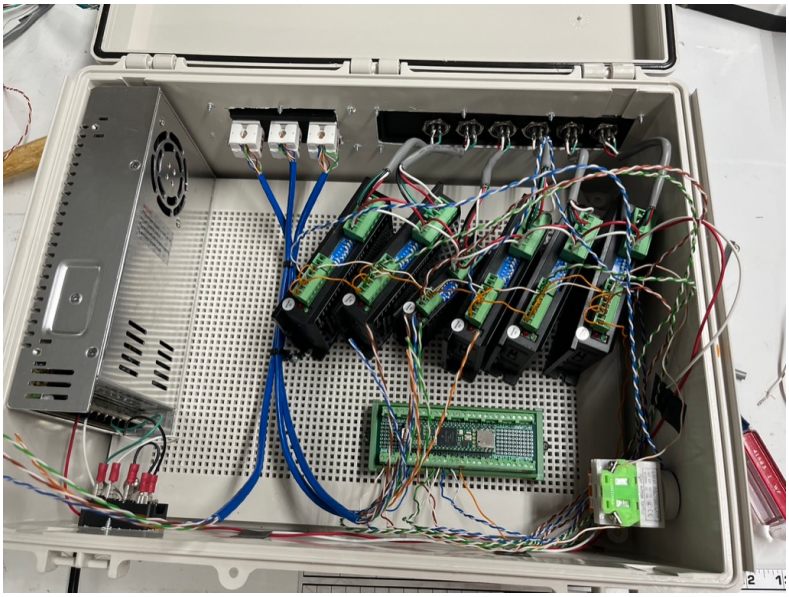
The holes are cut using an oscillating saw and the holes are drilled with electric drill.



Starting with the power supply to the power outlet and continuing to emergency switch and the stepper drivers to the outside aviation connectors are wired.

Although the manual indicated that the stepper drivers are to be screwed down before wiring, I found it too hard to tighten the wire clamps. They will be attached after fully wired.

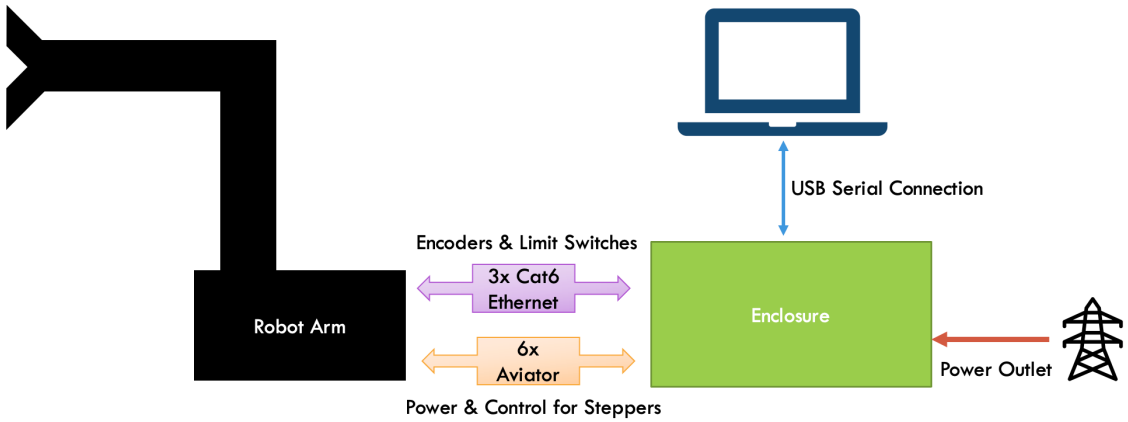
Connection to the Teensy to the Stepper Drivers is next. This is using separated cat5 cable.



After double checking continuity and referencing the connection the schematic, the enclosure is now fully assembled.

SYSTEM OVERVIEW & SCHEMATICS

There are main top-level components to this robotic system. The robot arm, control enclosure, and a computer for programming.

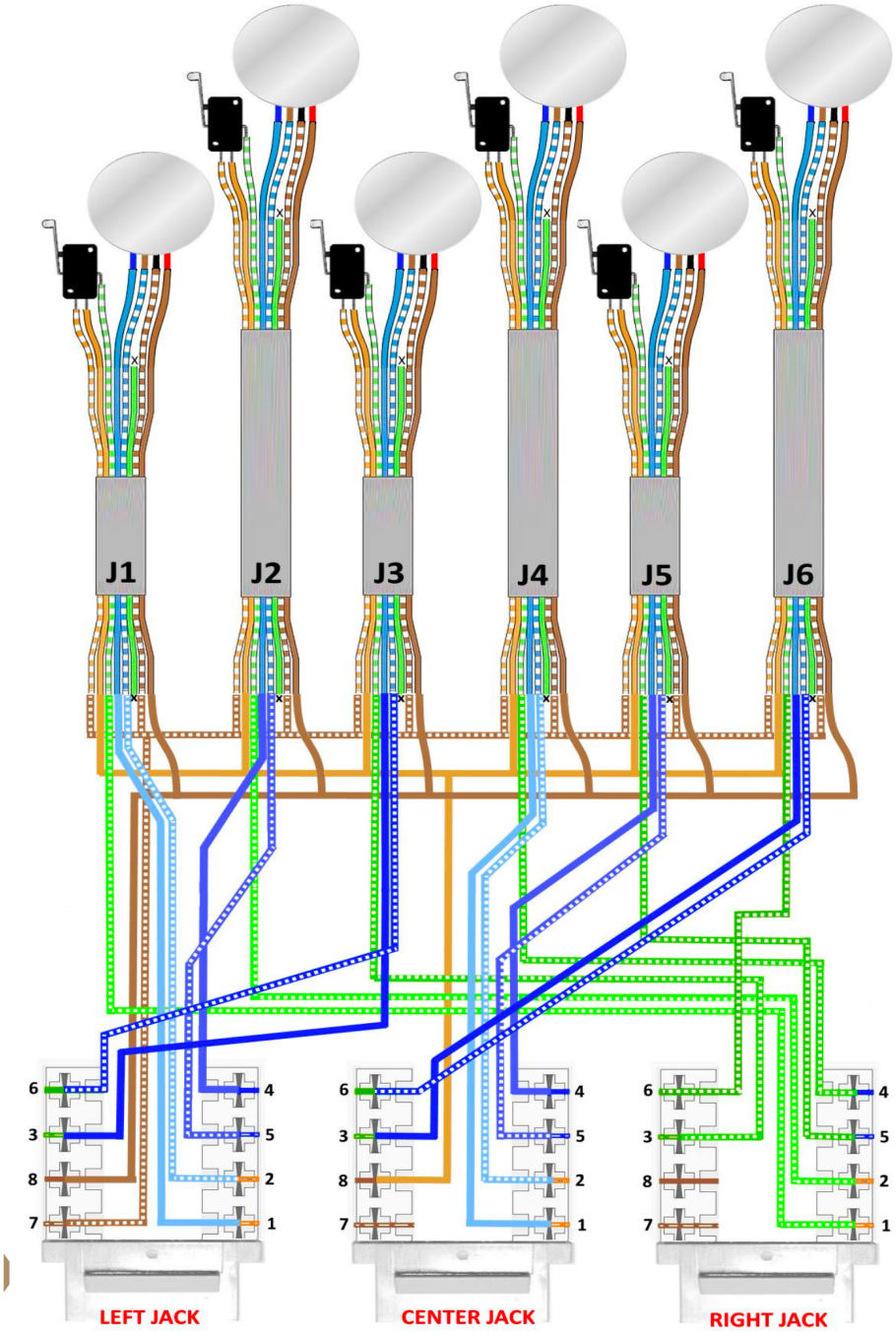


The enclosure has a standard computer power supply input, and this provides power to the stepper drivers inside. A computer running the AR4 Control program sends serial commands over the USB to the Teensy single board computer inside the enclosure. This is also how the Teensy receives its needed power.

Connecting the enclosure and the robot arm is 3 cat6 ethernet cables that provide encoder connections to the Teensy as well as the limit switches.

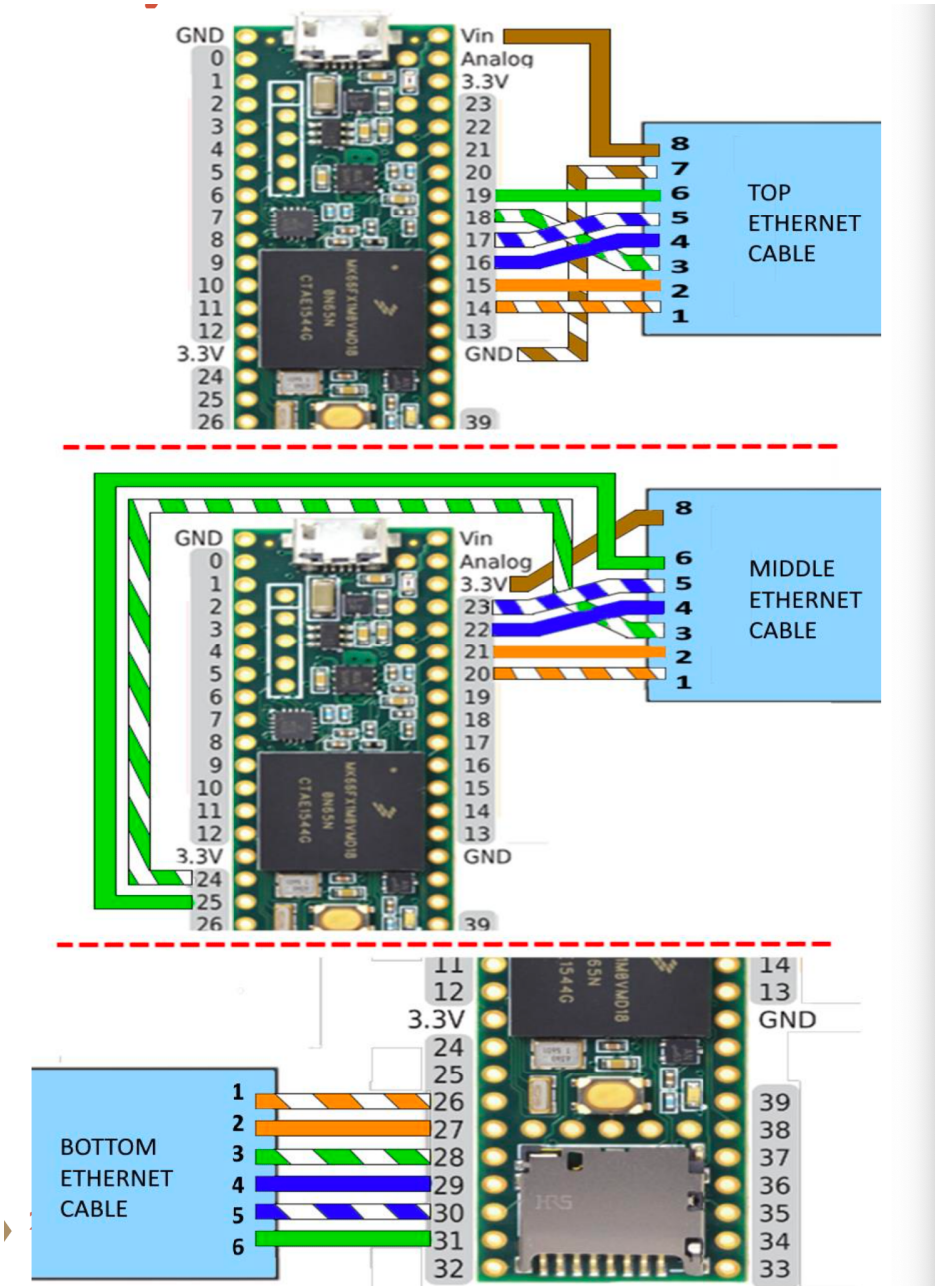
Power cables run for each of the motors from the steppers using the aviation connector wires.

ENCODERS, MOTORS, LIMIT SWITCHES ON ROBOT SIDE



Source: Annin Robotics AR4 Build Manual

ENCODERS & LIMIT SWITCHES ON ENCLOSURE SIDE



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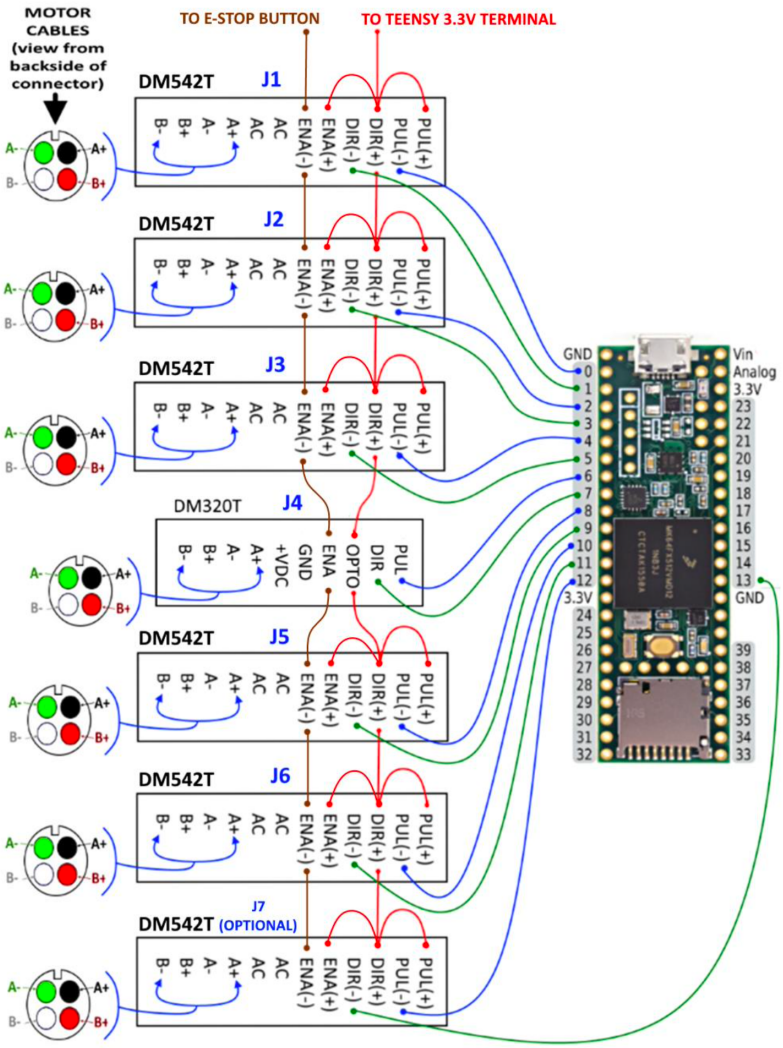
TEENSY & STEPPER DRIVER IN ENCLOSURE



Source: Annin Robotics AR4 Build Manual

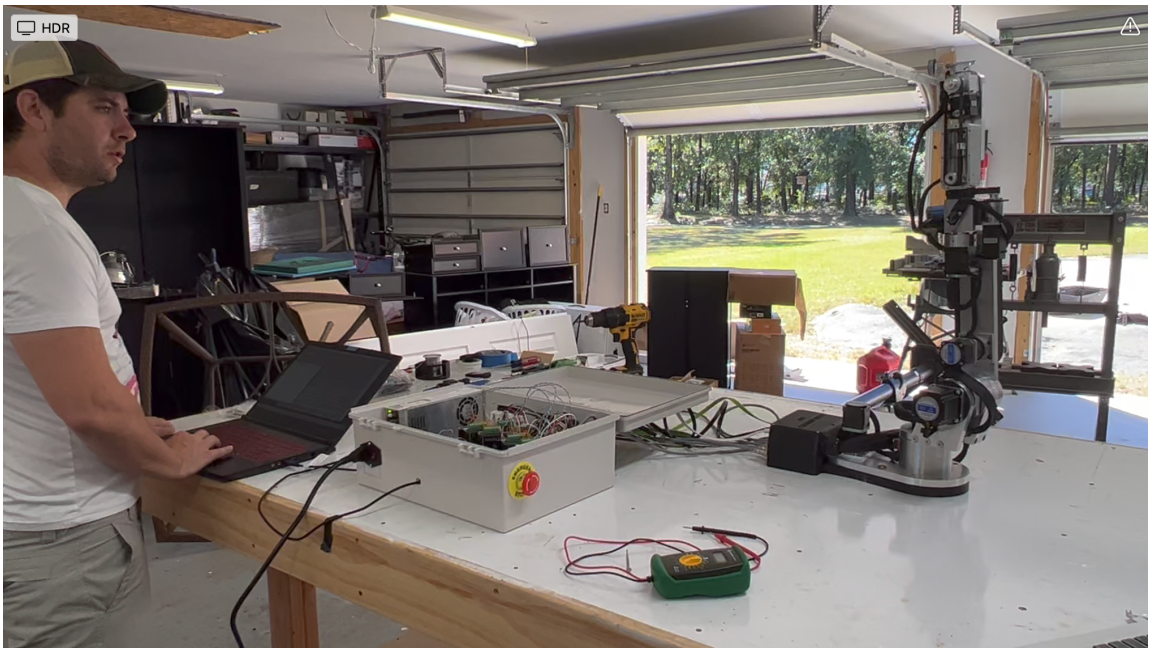
SOFTWARE & CALIBRATION

INSTALL SOFTWARE

- Teensy Driver: https://www.pjrc.com/store/teensy41.html#software
- Arduino 1.8 IDE: https://www.arduino.cc/en/software
- AR4 Control Software: https://www.anninrobotics.com/downloads

FIRST TIME SETUP & TEST

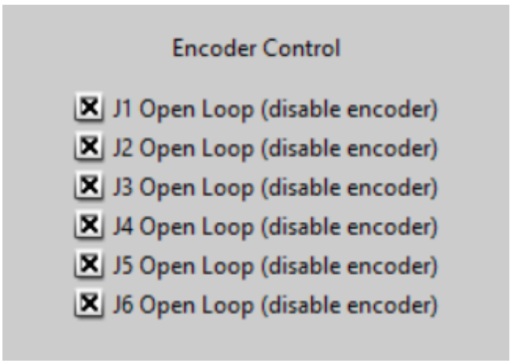
- Load firmware or Arduino "sketch" file to Teensy through Arduino IDE
- Run AR4 Control Software
- Disable Encoders
- Jog each motor and check direction
- Measure jog step with digital angle meter and ensure movement corresponds with amount expected*

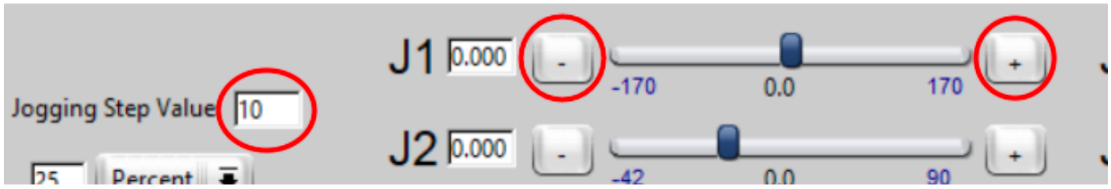


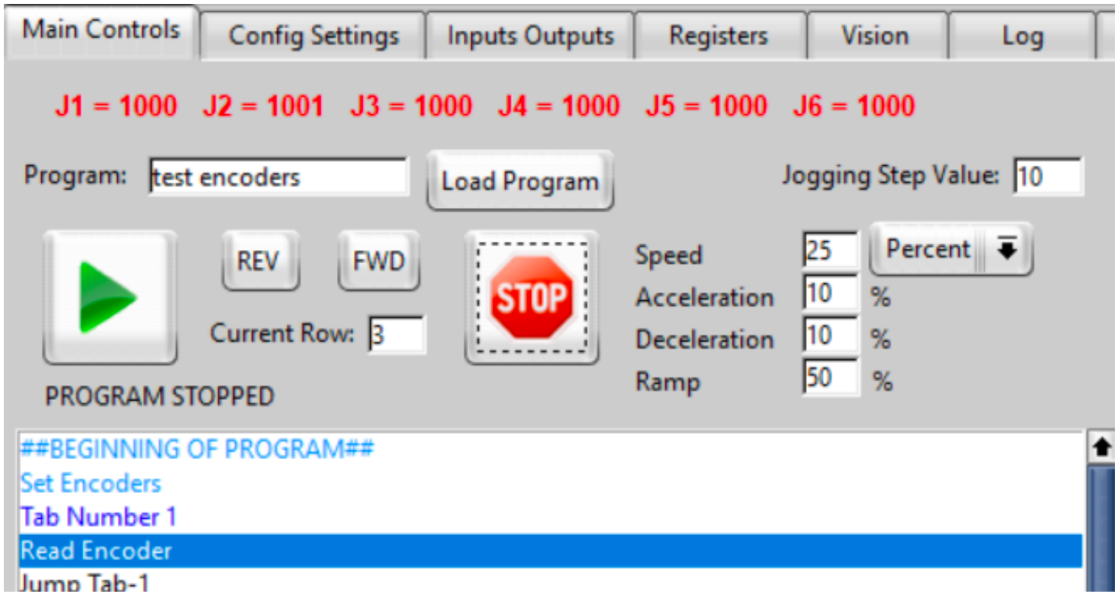
*It was at this point I realized J1 & J3 motors were swapped. This caused huge amounts of jog in one joint and very little in the other. After confirming there was no software fix as the motors are gears differently to carry the load of the arm, I had to surgically swap them. Luckily, I only had to de-solder one of the aviation connections and cut the extensions. I was able to keep all the cat6 connectors intact.

- Remeasure jog steps
- Load "test limit switches" program and ensure each work

- Turn back on encoders
- Load "test encoders" program and manually move joints to ensure values change are in correct orientation
- Run Calibration and enter offsets that are measured from angle gauge







Source: Annin Robotics AR4 Build Manual

APPENDIX

CITATIONS

1) Page: 261 - Annin Robotics AR4 Manual v1.3

ACKNOWLEDGEMENTS

- Chris Annin who designed this robot and provide the kit and excellent email support throughout the build of this robot

- Nick Carrsow & Teaun Tuner at Sea3D for printing the parts
- Joe Conrad who provided extra hands, brute strength, and wise tips on assembly
- Thomas Murrer who provided extra hands and the patience to do the J2 arm pressing twice
- Jordi Marin for allowing a few days off from work to finish on time
- My wife Jessica Murrer for extra hands and allowing all those late nights <3