Operation Manual

Team No: 12
Project Title: Articulating Robotic Arm for Wind Tunnel

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ABSTRACT

With the completion of the articulating robotic arm for a subsonic wind tunnel, a proper instruction manual on the assembly and operation is important. The project specification denote the intended use of the arm and what conditions were considered during the design phase. By using detachable aluminum plates for the housing design, the internal components (gears, rollers, bearings, etc.) are easy to install and align. This will keep assembly time to a minimum. Once assembled, the robotic arm is very easy to operate through the LabVIEW user interface. By typing a desired angle into the pitch or yaw input, the interface passes the command to the motion controller, which in turn runs the correct motors. Maintenance is only required after 50 hours of running the mechanism, after this amount of time some of the gears would need to be replaced.

ACKNOWLEDGMENTS

The Team:

Jacob Kraft - Team Lead:
Jacob is a FSU student from Stuart, FL. He has not claimed a specialty but has studied design and aerodynamics. He is a member of ASME (American Society of Mechanical Engineers) as well as a teaching assistant at the college.

Andrew Baldwin – Treasurer:
Andrew is a FSU student native to Tallahassee, FL. His area of concentration is aeronautics. He is a member of both Tau Beta Pi Engineering Honor Society and Pi Tau Sigma Mechanical Engineering Society. He also participates in Seminole Sound and is a former member of the FSU Marching Chiefs.

Justin Broomall – Secretary:
Justin is a FSU student from a small town in central Florida named St. Cloud. Growing up just sixty miles from the Kennedy space center, his childhood was filled with dreams of the final frontier. This drove him to pursue a mechanical engineering degree with a specialization in aeronautics.

Caitlan Scheanwald – Media:
Caitlan is a FSU student originally from Richmond, Va. She specializes in control systems and various programming languages. She plans to take her FE exam prior to graduation and pursue PE and PMP certifications. Currently, she works for the Department of Economic Opportunity as a project manager in software development.

Sponsor:

Dr. Michael J. Sytsma:
Dr. Michael J. Sytsma was born on March 15th 1982 in Homestead, Florida. He received his Bachelors degree (2004) in Aerospace Engineering with a Business minor from the University of Florida. Michael continued on to receive his Masters of Science in Aerospace Engineering from UF in 2006 studying Micro Air Vehicles. He began work at the Air Force SEEK EAGLE Office in 2006 as a loads engineer, and moved to the Air Force Research Laboratory in 2009 as a research scientist.

Recognition

Team 12 would like to recognized sponsor Dr. Michael Sytsma and Dr. Kumar for exceptional guidance throughout the design phase of this project. The team is grateful for Dr. Sytsma’s contributions and for allowing the team to visit the REEF center. Dr. Kumar has provided the team with a lot of help in regards to technical analysis of the system needed to finish he design process. Team 12 would also like to recognize the teacher Dr. Gupta for continued guidance throughout the semester.

1. Introduction

1.1.0 Project Specifications

The robotic arm was designed to be able to withstand and operate at the maximum forces produced by the low speed tunnel (22 m/s). By positioning the end of the sting over the housing center and with circular arc design, the center of gravity will not change when manipulated. The range of yaw manipulation is ±10° and the pitch angle manipulation range is -4° to 20°. Through the use of a worm gear, the arc is unable to move until a change in its position is requested through the user interface.

The dimensioning of the arc and the plates were crucial to the success of the project. Starting with an arc radius of 25”, the housing was designed be out of the flow of the wind tunnel. The top of housing had to be at least 17” below of the centerline of the expanding rectangular jet flow. The housing was kept compact, having a footprint of 8” x 5”, and having a total height of less than 7” from the top of the base plate. Running horizontally and vertically through the housing are multiple rubber rollers. By tightly tolerancing the vertical rollers to the sides of the arc, the arc is kept from moving left and right. The upper portion of the housing has a pair of horizontal rollers that compress down on the arc to maintain its position.

To control the motion of arc two motors were used. The pitch angle of the arc is adjusted through the use of a stepper motor and the yaw angle is controlled a rotary table. The two motors are run by a Galil motion controller; adjusting the to two angle positions individually when prompted through the LabVIEW user interface. Appendix A shows the motor data sheets.

1.2.0 Functional Analysis

The function of this project is to secure a test specimen in the center of the wind tunnel flow. The system must be able to move the specimen in the pitch and yaw directions during tunnel operation. This system utilizes multiple software and hardware. Figure 1 displays the system’s operational flow.

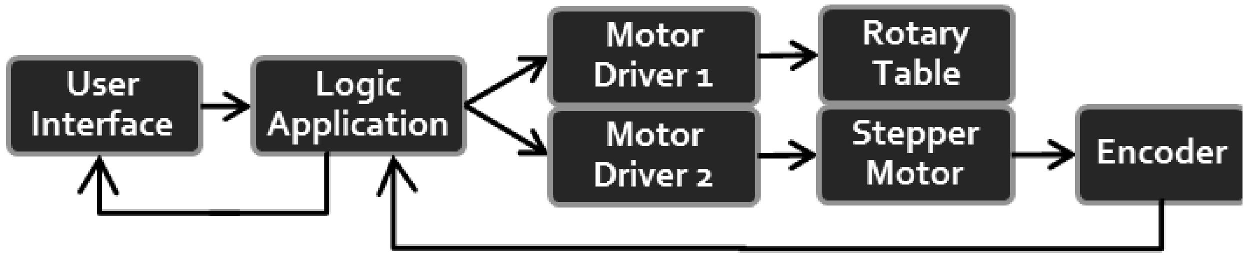


Figure 1: Operation Flow

The user interface is developed through LabVIEW. LabVIEW is also responsible for much of the logic application. It processes and compares the entered and current position values with data returned from the controller. It then sends commands to the controller for movement and program execution. The motor drivers for the system are internal to the Galil controller. Each one communicates with a motor to actuate the system. The stepper motor for pitch movement is equipped with an encoder which will feedback the motor's position to the controller. The controller will then send this information to LabVIEW to be processed. If the system movement is valid, a message will be returned to the user that movement is complete and the user will be able to enter new values.

The functional diagram in appendix B displays the program flow. It is important to note that a programming emergency stop will be connected into the entire system so that the program can be aborted at any time.

2. Product Assembly

The arc system consists of four main assemblies, the arc structure, roller support housing, power train, and the follower. To construct the arc, first use a high strength epoxy to bond the flexible gear track to the arc. Ensure the track has a quarter inch of clearance on both sides of the arc to allow proper translation while in the support structure. Once the epoxy has cured, fit the sting by placing the shaft through the milled hole in the end of the arc. Use the provided set screws to secure the sting in place. Figure 2 is an exploded view of the arc.

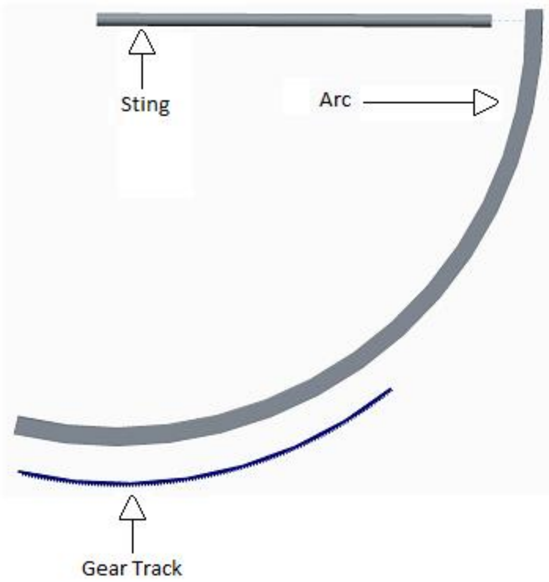


Figure 2: Arc-sting assembly

The roller support housing is the most critical force bearing assembly within the assembly. It is a combination of two housings, a top roller support housing and a bottom roller support housing. The bottom support assembly consists of three main plates, ten bearings, and two rollers on half inch shafts. The two side plates are placed on the bottom plate such that the bearings are facing inward, towards the other plate. Without screwing the plates in place, place the half inch roller assemblies in their respective bearings. With the rollers in place, use the 1/4-20 bolts provided and screw down the side plates to the bottom plate. It would be a good idea to use a semi-permanent thread lock adhesive, to ensure the bolts do not back out while in use. Once the side plates are secured with the rollers in place, the bottom support assembly is complete. The top support assembly is constructed almost the same way as the bottom support assembly. The assembly consists of three plates, eight bearings, and two horizontal rollers on quarter inch rollers. The vertical rollers are not placed into the support structure until both the top and bottom support structures are assembled and ready to be fastened together.

Note: the power transmission gears must be placed within the bottom support, before the vertical rollers, or the top support can be connected. The vertical rollers can be placed by hand into their bearings on the bottom support structure. Lastly the top support can be lowered onto the vertical shafts, and the bolts can start to be threaded. Keep the bolt loose to allow movement to integrate the arc. Figure 3 is an exploded view of the support structure.

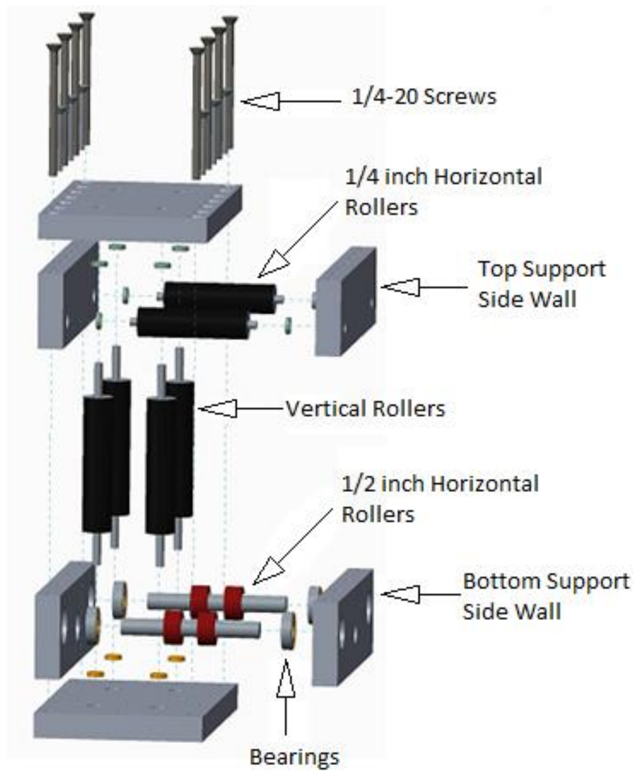


Figure 3: Housing assembly

The power train consists of the mechanical gears and motor used for arc manipulation, as well as their respective housings. The motor housing assembly consists of three plates and three bearings. The plates are arranged in a manner that the bearings will all face toward one another. The plates can be bolted directly together as there are no components that are confined within the structure. The powertrain consists of the motor, motor shaft extension, shaft coupler, worm, worm gear, power transmission shaft, spur gear, and two shaft collars for the power transmission shaft. The first step is to mount the spur gear and work gears. Begin by sliding the power transmission shaft through the outside of the motor housing, place the worm gear in the motor housing assembly and slide onto the power transmission shaft. Continue sliding the power transmission shaft through the other side of the motor housing, and through one side of the bottom support assembly. Slide one shaft collar, the spur gear, then the other shaft collar onto the power shaft, then continue to push the shaft through until it is flush with the outside of the bottom support assembly. Secure the shaft in place with the two shaft collars by sliding each shaft collar to the side of the support housing, and they make contact with the bearings. Tighten the shaft collars in place once they are in place. Once the shaft is in place align the spur gear and worm gear so that the geared section is directly centered in each of their respective housings. When they are positioned, tighten the set screw on the gear hub.

With the gears in place, the motor can be mounted to the motor housing assembly. There are four screws to mount the motor on the housing. The motor should be positioned so the connectors do not face the arc. Place the motor over the holes and bolt in place. With the motor mounted, slide the shaft coupler over the motor shaft, do not tighten the coupler yet. Slide the shaft extension into the housing through the bearing opposite the motor. Slide the worm over the shaft extension and continue to slide the extension until it seats against the motor shaft. Slide the coupler over both the motor shaft and tighten the coupler to both shafts. Spin the worm gear such that the worm will be positioned so that it meshes with the worm gear directly tangent to the shaft. When in position, tighten the worm in place by the set screw. Figure 4 illustrates a completed power train.

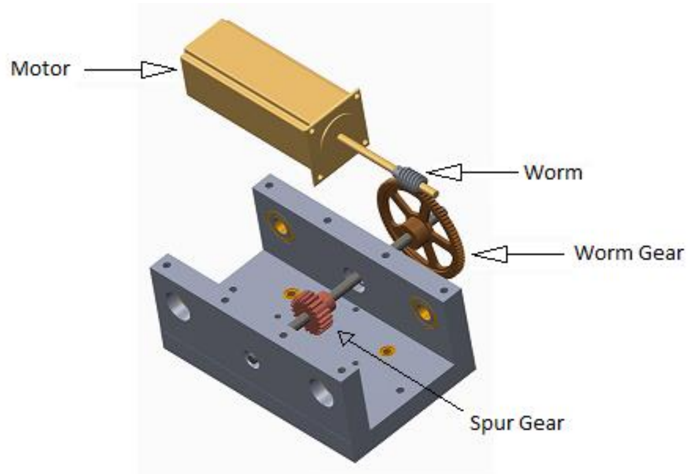


Figure 4: Drive train assembly

Lastly the follower assembly is critical for the arc to avoid bending while the model is in a side slip condition. The follower assembly consists of three plates, one square support rod, two vertical rollers, one horizontal roller, and six bearings. Again the rollers should be placed in their respective positions before bolting the structure together. With the rollers in place, bolt together the side and bottom plates with the 1/4 -20 screws. Once secured, the support rod can be bolted to the bottom plate. It is imperative that the support

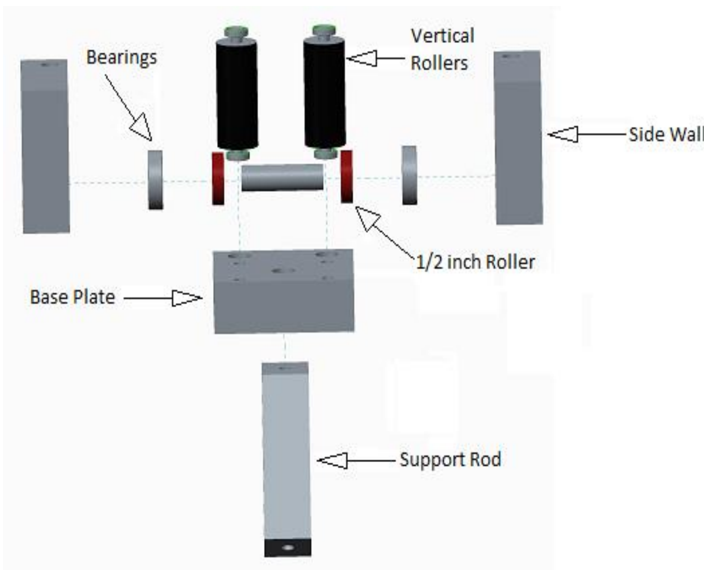


Figure 5: Follower Assembly

rod and the bottom plate be aligned such that the sides are parallel. This is easily achieved by placing the support and the rod in their side just before the bolt is tight. Doing so will allow the table to align the rollers and the rod itself. Figure 5 is an exploded view of the follower assembly. Figure 6 shows the complete assembly.

Figure 6: Full Assembly

3. Operation Instructions

3.1.0 Operation

Due to the design of this project, the user only need interact with the LabVIEW interface that has been created specifically for this system. In the event the Galil controller is reset or replaced (the program burned into the memory would be lost) we have provided a secondary LabVIEW VI which will re-download and burn the program to the Galil once more. The main interface, pictured in Figure 7, is what the user will be using to operate the system. The following list describes the operation window:

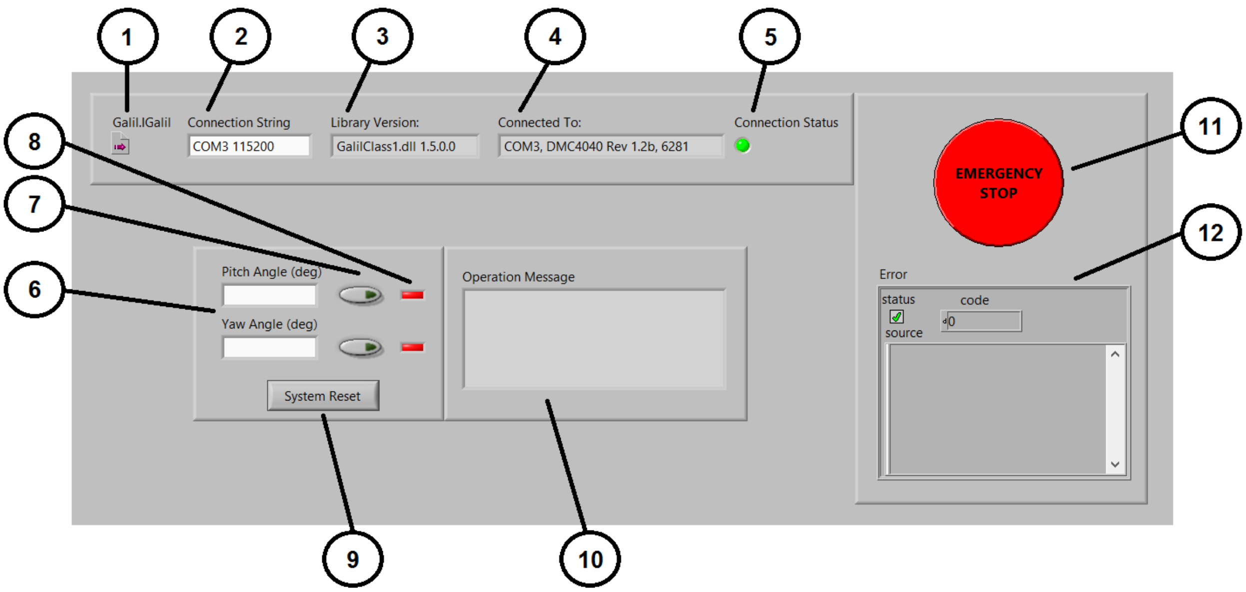


Figure 7: LabVIEW User Interface (Front Panel)

- (1) starts the program so the interface will be usable.

- (2) is a user entered connection string (this string will change per the computer being used, it is suggested to always use the 115200 setting because that is the faster processing), the displayed example is for serial connection, if network connection is to be used an IP address must be given to the controller and entered into the connection string box

- (3) will display the library version being run by the controller once a connection has been made, this is so that the user will always be sure of what library they have if any changes need to be made

- (4) will display the connected port (or IP address) and controller name if the connection is successful

***it is important to note that 3 and 4 will be empty if there is no connection

- (5) is an indicator linked to the connection status of the controller, in the example the controller connection has been successful and so the indicator is green, if there is no connection or a connection effort has been unsuccessful the indicator will be red

***it is important to note that the functions of 6, 7, and 8 apply to both rows of objects displayed, one row applies to the pitch movement and the other applies to the yaw movement

- (6) is a data entry field for the desired position of the specimen in degrees, there are separate data fields for each pitch and yaw

- (7) is a button to send the angle entered to the program for processing, it is important to note that the value is not sent just by entering it into the field, this prevents the program from having to be restarted for each movement and also helps to prevent accidental mistypes, when the button is clicked it will light up (bright green) and will remain pressed until the program has processed the value entered

- (8) is an indicator to display the status of the angle sent for processing, this indicator will always display red until an angle is entered, processed, and returned as valid, once an angle is returned valid and until the motion in the respective direction is complete the indictor will display bright green

***it is important to note that new angles can't be entered until the motion in both directions is complete and/or the angles entered are returned invalid

- (9) is the system reset, this will return the specimen to 0deg pitch and 0deg yaw

- (10) will display an operational message to the user, these messages have been set in the program and will display depending on the status of the system, some examples are listed:

    -motion has been completed, angle entered is invalid, system has been reset

- (11) is the emergency stop button, it is important to note that this only programically stops the system, it is important to incorporate an electrical kill switch into the entire system, this emergency stop is wired into each stage, therefore it can stop the program at any point

- (12) displays error codes returned by the system, this is separate from operational messages which are returned based on the system programming, error codes are returned by the controller and/or software. Once the system movement has been completed, new position values can be entered.

3.1.1Troubleshooting

In this section, we will discuss possible failure modes and troubleshooting methods in order to resolve these issues. We will break down these issues into a few different modes in order to direct you to the appropriate solution diagram. The troubleshooting diagrams shown in appendix B should aid the user in solving issues. They break down issues into mechanical and electrical issues and then provide practical solutions. If issues are not resolved through these diagrams, the user is instructed to call the manufacturer.

3.2.0 Regular Maintenance

In order to ensure proper lifecycle of the assembly, there should be regular maintenance checks and actions. The maintenance and actions required are broken down by hours of use in the following table. Many of the parts such as gears and rollers are given a life cycle based on a particular amount of use. As shown in the reliability section, they can endure up to 10^5 cycles. If a shaft rotates a maximum of 100 times an hour, this equates to an approximate life cycle of 100 continued hours of use. Recommendations for replacements begin at 50 hours in order to be safe and plan for future possible failures. Maintenance and checks include visual inspections, part replacement, lubrication, and alignment checks.

Table 1: Hourly Maintenance Chart

Hours of Use:	Action Required:	Purpose:
Every Use	Visual inspection	Use of damaged equipment
	Gear and bearing lubrication	Facilitates arc movement
	Check wire connectivity	Ensures proper communication
	Check gear connections	Ensures rigid connection for actuation
0-10	Lubricate	Smooth actuation
	Alignment Check	Looks for shaft and roller alignment
10-20	Lubricate	Smooth Actuation
	Check for gear wear	Protects against failure
20-50	Consider purchasing spare plastic gear parts	In case of failure
	Continued Inspections	Visual Wear inspection
50+	Consider purchasing spare rollers and flexi-rack	Connection might begin to detach

3.2.1 Spare Parts

Of the parts that were purchased for the completion of the prototype, there are few extra of excess parts. There will be leftover machine screws of varying sizes and thread count. In addition to this, there are extra lengths of steel rod stock in varying diameters and leftover flexible gear track. If there is any failure of the consumer off the shelf parts they can easily be replaced from McMaster, Grainger or QTC. The complete purchase orders are in D.

References

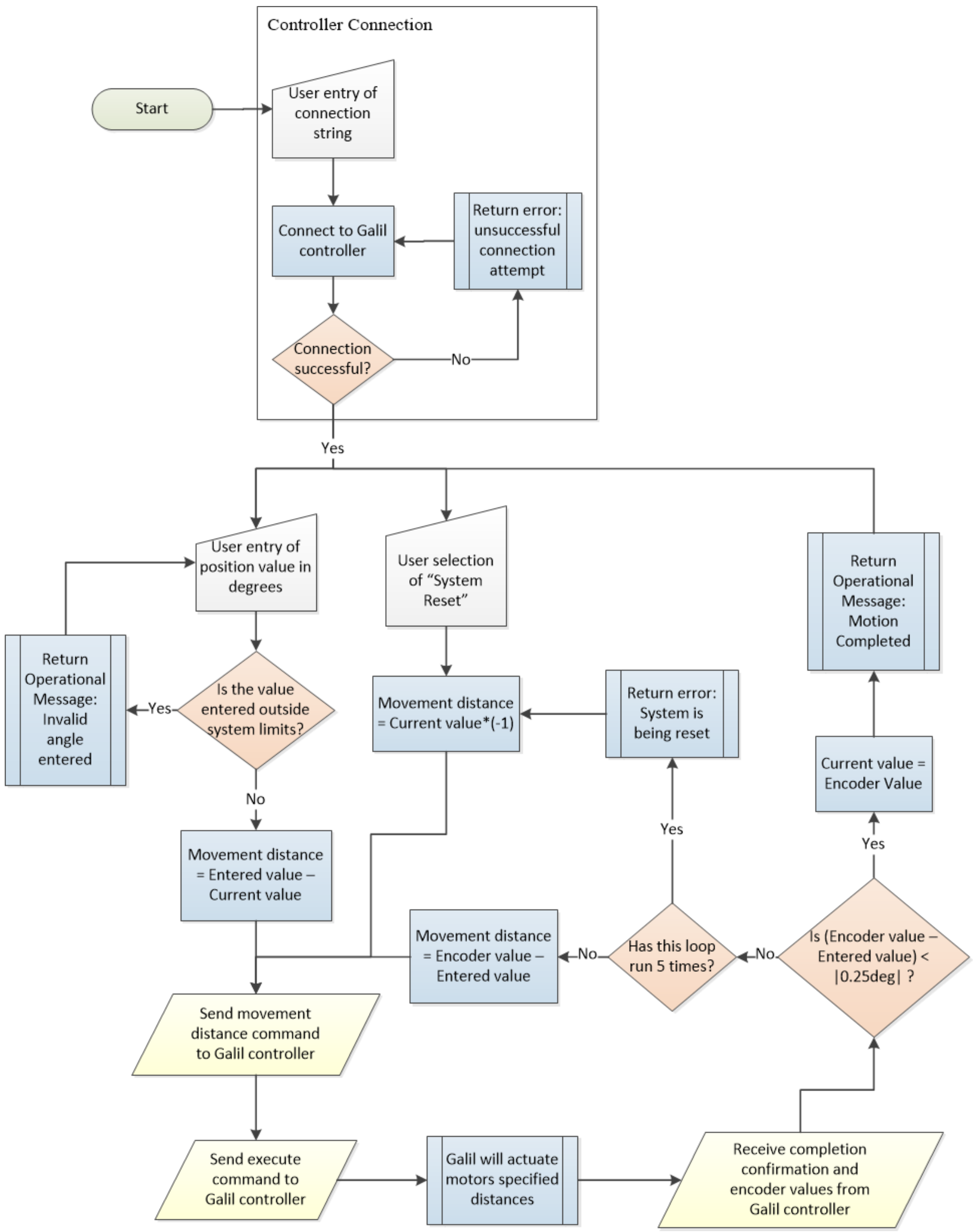
[1] N. Gupta .PHD, Florida State University, Tallahassee, FL, June 2014.

[2] R. Kumar PHD, Florida State University, Tallahassee, FL, June 2014.

[3] M. Sytsma PHD, University of Florida, Gainesville, FL

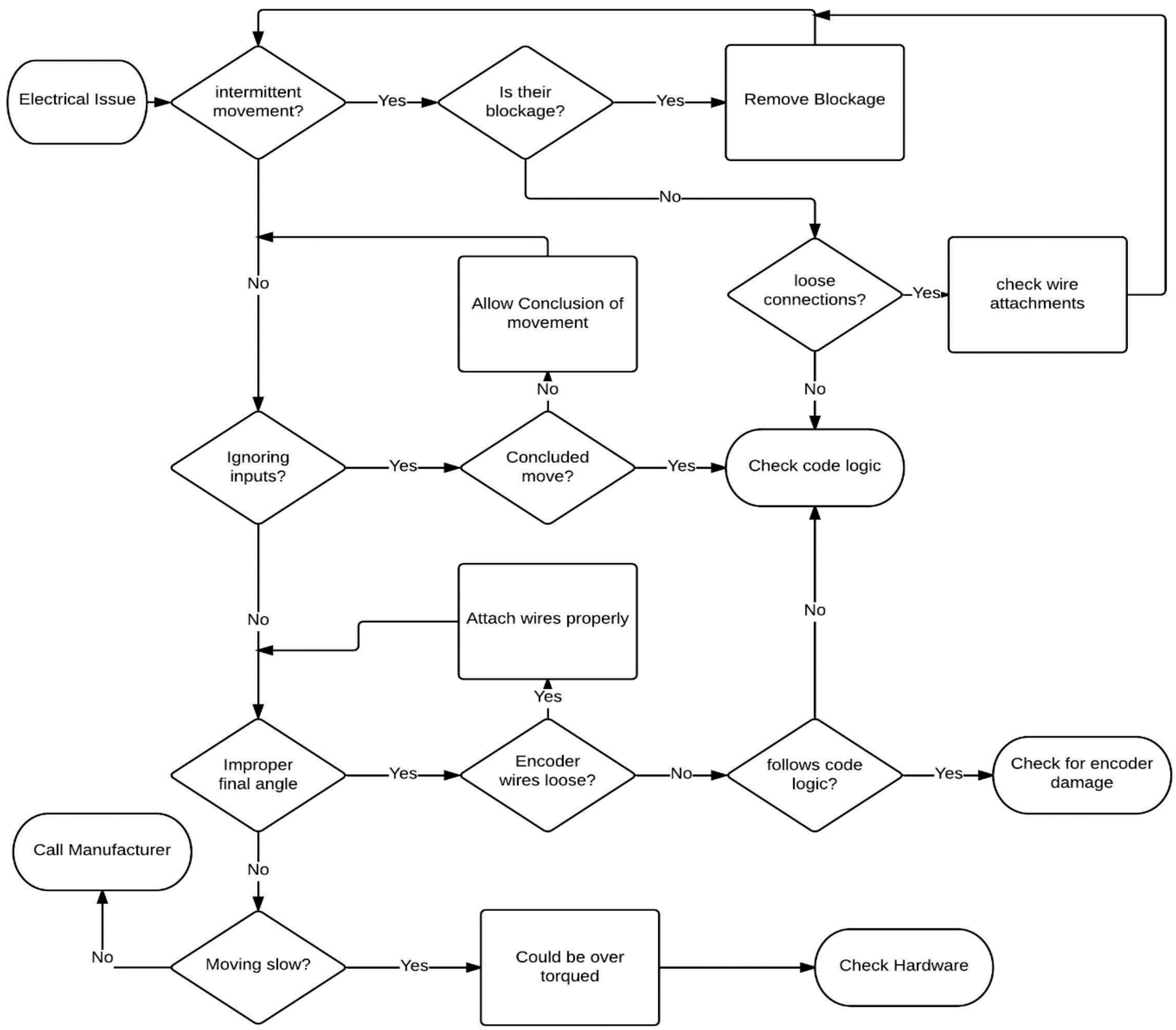
Appendix A- Specification Sheets

Appendix B- Functional Diagram

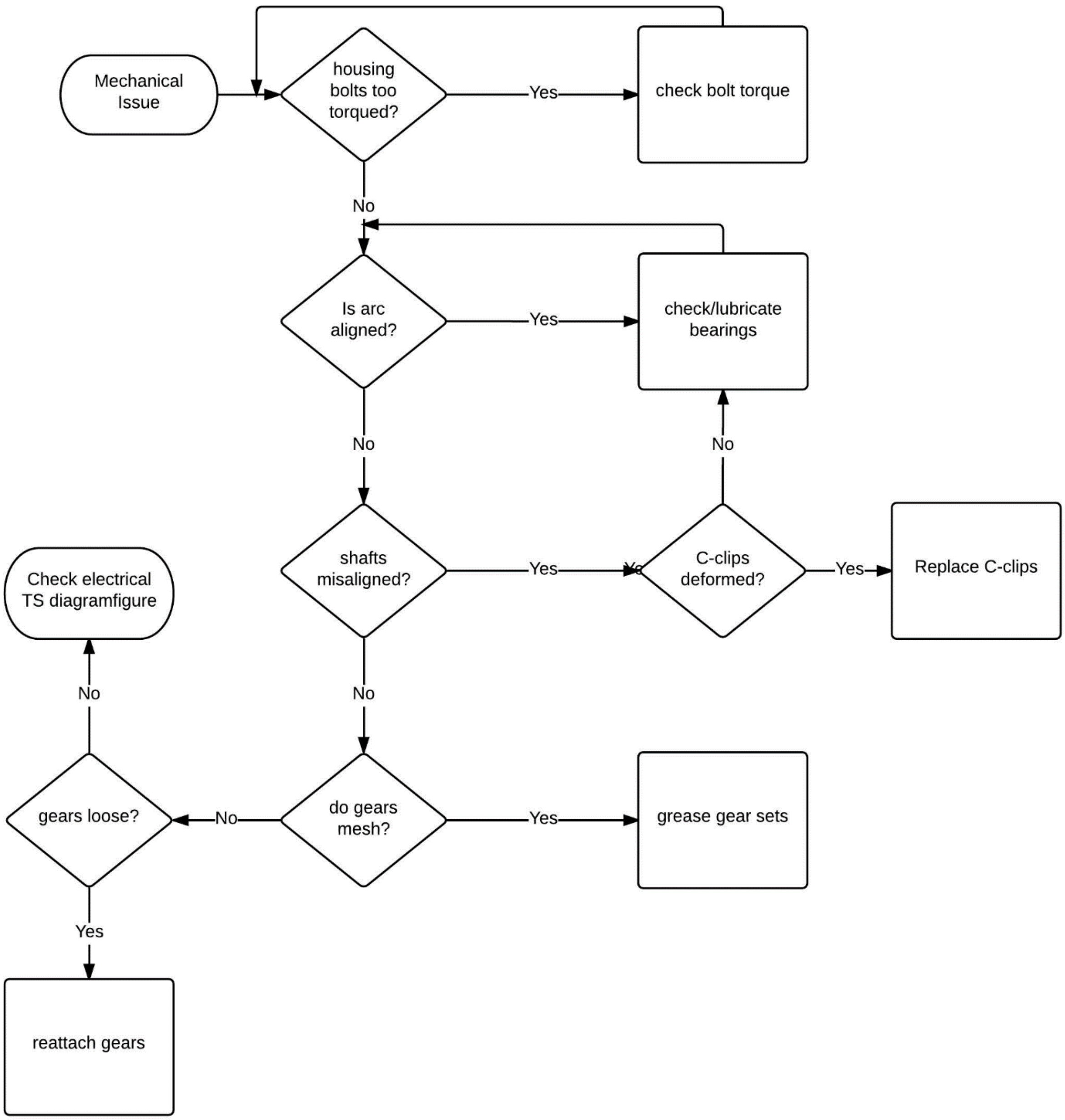


Appendix C- Troubleshooting Diagrams

Electrical TS Diagram



Mechanical TS Diagram



Appendix D- Purchase Orders