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| EE495/CME495 |
| Robotic Positioner System Alternatives Document |
| Revision 1 |

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| Thomas Hu, Jordan Smith, Jason Wong  11-30-2019 |

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# System Alternatives

## System Alternative Generation

System alternatives were generated based on different combinations of major components in the overall system. It was decided that the two major components of the system that dictate how the remainder of the system is designed are the:

* **Logic Control Device**. This device is used to control the overall system and translate user inputs into system operations. The device chosen from the list of alternatives must at minimum be able to interface with the chosen motor and the user input panel using General Purpose Input/Output (GPIO). It must be reprogrammable and retain its current program after a system reboot. The chosen Logic Control Device was chosen with consideration of these requirements along with performance and ease-of-implementation. The following devices were considered:
  + Field Programmable Gate Array (FPGA)
  + Programmable Logic Controller (PLC)
  + Microcontroller
* **Motor**. A motor is required to fulfill the requirement of being able to rotate the system electrically. Hydraulic motors were not considered due to lack of expertise and the desire to keep the system entirely electrically dependent. The motor was chosen based on its torque and rotations-per-minute relationship, difficulty of implementation, and cost. Cost is an important consideration due to the motor being one of the most expensive system components. Finally, safety was taken into consideration when eliminating possible choices. The following motors were considered:
  + Induction Motor
  + Servo Motor
  + Stepper Motor

Of the two components, the motor is the component which affects the overall design of the system the most. It affects the way the circuitry is designed to provide power to the system, as well as what kind of power will be used in the system. The logic control device selection will likely affect the circuitry design of the system; however, the overall functionality and design of the system will stay the same.

The design of the rotator subsystem will be heavily affected by specific model of motor selected. This is because the motors examined do not provide the necessary torque required to meet the client’s performance requirements without using a gear reduction system. Gear reduction will enable the motor to significantly increase its torque at the expense of speed. The exact configuration of gear reducers will be decided upon selecting a specific motor type because it depends on the torque and speed that the motor can supply.

The major component alternatives considered are described in detail in Section 1.1.1 and 1.1.2 for the Logic Control Device and Motor, respectively. The advantages and disadvantages of each component alternative will be listed, along with an in-depth description of the component.

### Logic Control Device Selection

#### FPGA

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| **Advantages** | **Disadvantages** |
| - Precise  - Flexibility | - High relative cost to other alternatives save the PLC.  - General purpose device, will have unneeded functionality.  - Difficulty of implementation. |

If precision and accuracy is valued above all other requirements, an FPGA would be the most ideal device to use. A system utilizing an FPGA will be more precise and accurate because of the ability to optimize an FPGA to suit the exact needs of a system. FPGA’s have low analog-to-digital conversion process and operates at a comparatively low level, which allows for the most accurate system performance.

The main disadvantages of using an FPGA are that they tend to be more expensive compared to the other alternatives that were examined, besides the PLC. In addition, the memory management and infrastructure are not built into an FPGA, which raises the difficulty of implementing the device within the project timeline. Additional features are more difficult to add in the event that the client desires more features in a possible future system upgrade.

#### PLC

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| **Advantages** | **Disadvantages** |
| - Ease of implementation  - Reliable | - High relative cost to other alternatives  - Full factory automation not required  - No current PLC expertise within the project team |

A PLC device is widely used in industrial environments for its reliability and simple programming language. The device can perform all the required system functionality, and development using a PLC would be relatively straightforward to fit in the project timeline.

Disadvantages of using a PLC is that it is the most expensive type of device of the possibilities examined for this system. While easy to implement, the device is unfamiliar to all members of the team. There will be extra time required to learn how to use the device and develop for the user application. A system that utilizes a PLC device will require an encoder for information on the motor position, which can be difficult to implement during the integration process. The final disadvantage is that the client does not require the benefits that a PLC provides in that it can be used to automate many machines in a factory with ease.

#### Microcontroller

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| **Advantages** | **Disadvantages** |
| - Ease of implementation  - Inexpensive  - Flexibility |  |

A microcontroller provides many benefits in it being the simplest to implement device when considering the experience of the group. Implementing features such as the recall function will be simple using a microcontroller because of its comparatively high-level programming language. The amount of available GPIO pins on commercial microcontrollers provides a large amount of flexibility, and the ability to rapidly deploy code will quicken the integration testing process. Finally, microcontrollers are very inexpensive when compared to the other alternatives considered.

There are no discernable disadvantages to using a microcontroller as the logic control device.

#### Selected Logic Control Device

Based on the advantages and disadvantages of the logic control devices examined, it was decided that a microcontroller-based solution will be used. The main reason why the microcontroller was chosen is due to the ease of implementing a microcontroller solution. The group has prior experience with microcontroller development, and it would not be the impeding factor in completing the system before the project deadline. Integration testing with a microcontroller will be simpler in comparison to the FPGA and PLC and new features can be added with relative ease in the case that the client requires more functionality in a future system upgrade.

### Motor Selection

#### Induction Motor

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| **Advantages** | **Disadvantages** |
| - Inexpensive  - Easy to maintain | - Requires a variable frequency drive (VFD) for speed control  - High inrush current when under heavy loads  - Requires external positioning sensor for closed loop control. |

An induction motor-based solution has advantages in that the motor itself has a simple and rugged design. The motor will require little maintenance due to its brushless design and is cheaper than a DC brush motor.

Limitations of the induction motor include that these motors typically operate at its rated speed and require a variable frequency drive (VFD) if speed control is desired. When a load is applied, the motor will not be able to reach its rated synchronous speed. In addition, the possibility of inrush current reduces the safety in an induction motor implementation. Inrush current may reach values of 5 times the rated full load current (FLA) if the motor is rotating a large load. Lastly, there is no internal rotor position tracking built into an induction motor, meaning that a VFD and motor encoder will be required to achieve closed loop control.

#### Servo Motor

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| **Advantages** | **Disadvantages** |
| - Built in closed loop feedback system  - Uniform torque within nominal operation speeds | - Expensive |

A servo motor-based solution provides advantages in it being a near constant torque curve at a wide range of speeds. It delivers relatively high output power for its size and weight when compared to other motors and operates in closed loop feedback using a drive controller and built-in encoder. This allows high positional accuracy to be achieved.

The main disadvantage in choosing a servo motor is its cost, which is higher than the other motors examined.

#### Stepper Motor

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| **Advantages** | **Disadvantages** |
| - High torque at lower speeds  - Can be operated in closed loop feedback  - Inexpensive | - Lowered torque at higher speeds  - Noisy |

A system that utilizes a stepper motor will be able to provide high torque when operated at a low speed. However, the drop-off in torque at higher speeds will complicate finding a suitable stepper motor which will hit the required performance targets for the system.

#### Selected Motor

Of the motor types examined, it was decided that a servo motor would best suit the needs of the client. The main reason why the servo motor was selected was because many servo motors come as a “complete” package, meaning that the encoder is built in which will decrease the complexity of the system and integration difficulty. The uniform torque/speed is extremely desirable for its reliability, and the motor does not suffer the dangers of inrush current. While the servo motor is more expensive than the other alternatives, there is a possibility that the overall component cost for a servo implementation is lower due to there being no need to purchase encoders for closed loop feedback control.

## Conclusion