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Individual Component Analysis: Programmable Logic Controller Selection

SE_Automation-for-spectrometry-measurement (Team 4)

Project Background

Our project will require the use of a Programmable Logic Controller (PLC) as it must interpret the state of another machine. The other machine is a Glow Discharge Spectrometer (GDS) which gives the elemental composition of a metal alloy sample. The GDS communicates via ethernet to an outside computer which understands the state of the GDS and serves as a human-machine interface (HMI) to operate the GDS. This 2-way communication requires a person to mitigate the communication process and to physically place the sample onto the GDS to analyze the sample. Automation of this process requires a PLC as it is capable of understanding the state of the GDS and will command an outside mechanism to place the sample onto the GDS, thus automating the process.

The selected PLC must have ethernet capabilities in both the physical and software aspects as it must be able to interpret the state that the GDS is at. It must also be able to send messages to the computer to allow the GDS to analyze the sample as if a person were commanding it. Additionally, if some fault were to occur the PLC must behave accordingly. This will be achieved by writing the logic in the PLC. The software of the PLC where the logic is written will have to be open source as this would make it user-friendly. The PLC will need a large number of output ports to be able to command the mechanism and must have some input ports as they will likely be used to jog the mechanism that will place the sample onto the GDS during a calibration phase.

Information Learned

The research conducted during this assignment has solidified the selection of the controller to be used for this project. The first step to identifying what PLC to purchase is to outline the needed requirements. This includes the inputs and outputs of the PLC, communication protocol, and price point. The best PLC for this project is the P1K offered by Automation Direct. When compared to other PLCs 3 main features make it superior. This includes the price, high customizability, and software. Out of many PLCs looked at, the P1K has the lowest price point. It is a cheap PLC as it does not have the large features that many PLCs are needed for complex systems. This is desirable as our system is relatively small and not complex. Meaning that a simple PLC such as the P1K will be best suited for the automation of the GDS. The P1K does need expansion modules to function correctly. Even so, the addition of the expansion modules is still at a price point that is cheaper compared to other PLCs. These modules are simple to add to the P1K CPU. They are simple physical attachments making the PLC highly customizable. If additional inputs or outputs are needed then a purchase of the modules can be justified. There are 5 combo I/O modules, 18 Input modules, and 13 output modules for the P1K CPU giving a large range of I/O. For a simple system on the GDS, at most there may be 3 or 4 modules need. Each varies in price from $80.00-$159.00. The P1K uses open-source software meaning that the PLC can be programmed via ArduinoIDE or Mu which uses C++ or Python as desired. The only challenge to these languages is having to access libraries that allow for PLC functions and ethernet communication. Due to the low complexity of the project, the selection of the P1K PLC can be solidified as the other PLCs have large cons that make them undesirable for our project.

Information Gathering Approach

Keywords used

Automation, Mechanical Automation, Programmable Logic Controller, Motion Control, Programming Logic, Arduino Compatible, I/O module types, Stepper Motor Inputs, Encoder Output, Solenoid Inputs, Linear Actuator Inputs, Sinking and Sourcing I/O, Ethernet Communication Protocol

Articles and Webpages

What is a PLC and advantages to automation:
https://telstarinc.com/what-is-plc-and-why-use-it/

How to select an appropriate PLC:
https://www.maderelectricinc.com/blog/choosing-the-right-plc-6-things-to-consider

PLC selector based off preferences/needs:
https://www.automationdirect.com/systembuilder

PLC Different program types:
https://inductiveautomation.com/blog/plc-programming-languages-go-beyond-ladder-logic

General I/Os in a PLC:
https://www.pdfsupply.com/blog/index.php/2022/05/23/examples-of-plc-inputs-and-outputs/

Arduino PLCs:
https://circuitdigest.com/tutorial/an-overview-of-plc-and-various-arduino-plc-boards

Phone calls and emails:

Phone call with Jim from Automation Direct
Specific Inquiry about the Productivity 1000 Open Source PLC (Will refer to P1k)
Case Number: 01612227
Subject: PLC inquiry
Phone Call Length: 13:56s (Includes navigating through menu)

General Notes:

- Customer service was fast, call picked up immediately, talked to a representative quickly that knew the product specification
- It is an Arduino based PLC
- Unlike other PLCs, the p1k does not constantly check inputs and outputs.
    - Arduino IDE goes from top to bottom meaning if it is not in a loop it will not update input and outputs
    - Software support is not specific. That is if we have software questions we will have to figure it out based on specific examples available on the internet
- Typical sampling rates for these modules are in the milliseconds
- MicroSD slot available for logging of the PLC (data logging)
- Does not include battery backup
- Uses the Atmel SAMD51P20 microcontroller
    - 120 MHz
    - 1MB of Flash memory
- Limited to 15 I/O modules

The email to Miguel Mejia was never sent, as the P1K has already been purchased. However, initial contact included the Omron Specification sheet which guided in the selection of the P1k. The Omron PLCs are a large investment making it an option that would not be feasible for our project.

Remaining Questions: (specific to the P1K as this was bought)

- Library of ethernet functions must be looked into in depth
    - Pycomm3 is a library for communicating with PLCs using Ethernet/IP
- What will the physical system need (definite list of inputs, outputs)
- Output specifications may limit the capabilities (i.e. only 1A of current is sent); if a component needs more than this, then an external power supply may be needed to power these components. How can this be done?

Detailed Description of Findings:

Comparison Table

Product	Omron PLC: CP1L-EM	BRX Do-more PLC: BX-DM1E-M-D	Productivity 1000 PLC: P1AM-200
Pros	- Ethernet compatibility - Expansion Modules are available, but not required to function - Highly Customizable - Large selection of I/O modules	- Built-in backup battery - Highly Customizable - Large selection of I/O modules - Mid-range Price - Free software download - Built-in simulator	- Highly customizable - Larger selection of I/O modules - Lowest Price - Software is open source - Software is well known
Cons	- Expensive - Software Licence needed, meaning future software changes may be difficult - Large order fulfillment time	- CPU component only - Expansion Modules needed to function - An ethernet communication module must be purchased	- CPU component only - Expansion Modules needed to function - Ethernet communicati on module must be purchased
Vendor	DigiKey (92 in stock, 4 week lead time)	Automation Direct (93 in stock, 2-day shipping)	Automation Direct (50 in stock, 2-day shipping)
CPU Cost	$ 937.37 (Excluding expansion modules)	$ 354.00 (Excluding expansion modules)	$ 109.00 (Excluding expansion modules)
Expansion Module Cost (e.g)	$ 398.91 (12 inputs; 8 Outputs, discrete)	$ 69.00 (8 inputs; 4 outputs, discrete)	$ 85.00 (8 inputs; 7 outputs, discrete)
Software/ Coding Language	CX-One (Omron software); Coded in structured text	Do-more! (Automation Direct software), Block structured programming	Open Source Software (ArduinoIDE and

			muPython, C++ and python

How components work:

The specific PLCs listed above are modular units. This means that additional modules can be added depending on the system needs. Not all PLCs are built this way, however having this as an option is essential in the GDS automation system. The GDS automation system is not mature enough to buy a PLC that does not contain expansion modules as there already have been changes in the design that require additional input and outputs.

Regardless of the hardware, all PLCs serve the same purpose. That is to read inputs to determine what state the system is at. This includes faults, ready-to-execute code logic, completed code logic, etc. All of these parameters are based on the state of the hardware which is communicated to the PLC via software. Once the PLC knows the state that its at it acts accordly. This is done by programming the PLC with code that contains the desired logic. The logic of the PLC can come in many forms and include Function Block Diagram, Ladder Diagram (LD), Structured Control Language (SCL), Graph, and high-level languages such as C++ and Python. The choice is up to the user, however, PLC companies more often than not use proprietary software. This may be a challenge for new users who do not have a coding background with these specific proprietary software. Once the PLC executes the software logic then some outputs are commanded as determined in the logic. At this point, the cycle repeats itself until the task is complete.

Inputs and outputs (I/Os) of the PLC can be categorized as two types. These are discrete I/Os or analog I/Os. Examples of discrete I/Os include a switch to determine if something is on or off without anything in between. Analog I/Os can have a state in between on and off such as seen in a light dimmer. There are 2 sources of inputs which include data coming from a device or data coming in from a user input. Input devices include sensors or other PLCs and user inputs include starting or stopping the system. Output devices come in many different forms which include opening or closing a valve and changing the speed or distance of a motor.

Primary Sorce:

https://inductiveautomation.com/resources/article/what-is-a-PLC#:~:text=A%20PLC's%20operation%20is%20broken,to%20any%20connected%20output%20devices.

Features of a PLC that are not driving, but need to be kept in mind:

The speed of the PLC is a feature that is determined by the PLC's central processing unit (CPU). A complex or large system will require a large amount of processing power which will reduce the speed of the PLC. Typical CPU speeds range from 1MHz to 1 GHz, which indicates the number of cycles taken in 1 second. For the purpose of automating the GDS, the system will not be complex enough to need to only consider high-end PLCs with large CPUs. The automation system will only contain 1 mechanical system with a limited number of inputs making a simple and small system. Memory capacity is another parameter of a PLC that is affected based on the size and complexity of the system. This parameter stores data temporarily during the execution of the control logic. Again, for the purpose of our system this is not a driving parameter since the automation system is not large (containing more than say, 20 outputs) and will not be complex.

Redundancy in a PLC is a nice feature to have in a PLC. Redundancy ensures that a backup system can take over in case of complete failure. Redundancy can be implemented in the hardware if the system can be achieved by duplicating components. This is not a parameter that will be done as it will affect the provided budget, but can be seen in the regular prototyping stages of the creation of a PLC's system. Software redundancy can include the use of 2 PLCs where each PLC monitors each other's outputs. Again in the scope of the project, this is not needed, as the proposed system is not complex.

Another factor that may affect the PLC is the environment in which it will be placed. These parameters include temperature, humidity, dust, chemical exposure, vibrations, and EMI. Many if not all of these can be mitigated by using a control box. Additionally, the environment that our system will be placed is in controlled. The environment is in a research lab with other research equipment that needs to be performed in a non-harsh environment.

Primary Sources:

https://unicourse.org/wp-content/uploads/2020/04/U15-WB-1.pdf

https://www.automationit.com/blog/80-choosing-a-plc-things-to-consider

Overall understanding of these have helped in the selection of the PLC.

Appendix:

Other websites used:

How a GDS works:
https://www.horiba.com/int/scientific/technologies/glow-discharge-optical-emission-spectroscopy/glow-discharge-optical-emission-spectroscopy/

What is the OSI model? CloudFlare
https://www.cloudflare.com/learning/ddos/glossary/open-systems-interconnection-model-osi/

P1K datasheet:
https://cdn.automationdirect.com/static/specs/cutsheet/P1AM-200_cutsheet.pdf
https://cdn.automationdirect.com/static/specs/p1am200specs.pdf
P1K Expansion modules:
https://cdn.automationdirect.com/static/specs/P1-16ND3.pdf
https://cdn.automationdirect.com/static/specs/P1-15CDD1.pdf

Omron Datasheets:

OMRON

CP series CP1L CPU Unit
CP1L-EM□□D□-D/CP1L-EL□□D□-D
CP1L-M□□DR-A/CP1L-L□□DR-A

High Performing Programmable Controller with Embedded Ethernet

- "CP1L-EM" and "CP1L-EL" has a standard-feature Ethernet port.
- "CP1L-M" and "CP1L-L" has a standard-feature peripheral USB port.
- Function blocks (FB) allow you to build up modular structure and programming of ladder diagrams.

CP1L-EL CPU Units with 20 Points | CP1L-EM CPU Units with 40 Points | CP1L-L CPU Units with 10 Points | CP1L-M CPU Units with 60 Points

Features

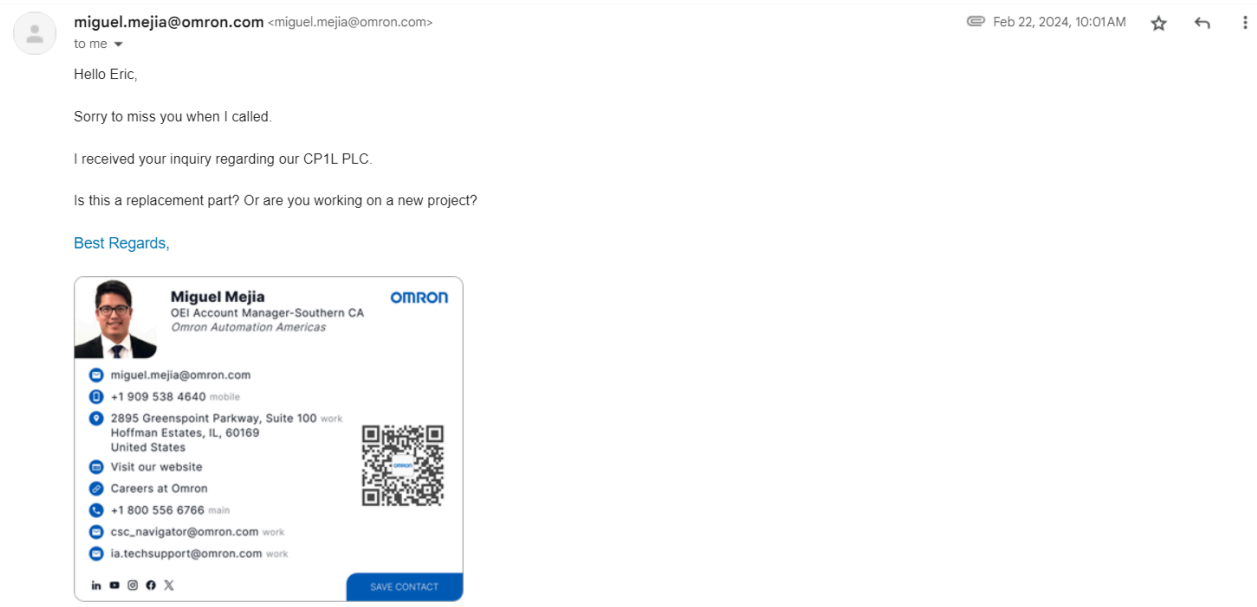
- "CP1L-EM" and "CP1L-EL" have complete with a Ethernet port.
- Pulse output for two axes. Advanced power for high-precision positioning control.
- High-speed Counters. Single-phase for four axes.
- Six interrupt inputs are built in. Faster processing of instructions speeds up the entire system.
- Serial Communications. Two ports. Select Option Boards for either RS-232C or RS-485 communications.
- "CP1L-M" and "CP1L-L" have a peripheral USB port.
- The Structured Text (ST) Language. Makes math operations even easier.
- Can be used for the CP1W series Unit. The extendibility of it is preeminently good.
- LCD displays and settings. Enabled using Option Board.

https://assets.omron.com/m/403180c254de9134/original/CP1L-Datasheet.pdf

Phone Call and Email:

Phone call to automation direct outlined in Phone “Information Gathering Approach”

Email received by Miguel (attached was a pdf of the vast selection of PLCs provided by Omron)



No further contact was made beyond this point as the P1K controller was purchased. However further contact with automation direct is expected when needed for hardware support and general inquiries on the expansion modules.