# Laboratory Control System for Engineering Cleanroom

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*Abstract*— **The Laboratory Control System (LCS) for the engineering cleanroom is designed to provide access control to individual pieces of equipment in order to create accountability and make the billing process more efficient. Features of the system include: expandability, access control, online reservation creation, administrative control, and ease of use.**

## I. INTRODUCTION

Control Systems are used throughout many different fields to regulate the behavior of devices or machines. From the most common association of production to more recent implementations in artificial intelligence, we see application in almost every aspect of the modern world today. The Control System to be designing is for the Clean Rooms that exist in engineering building one, and are used for all Electrical and Computer Engineering PhD Candidates and Professors. The idea is to provide accountability, and ease of use into these rooms that currently only have a sign-in sheet to show the date, time, and machine that was used. However, this type of system that is currently used, creates several problems.

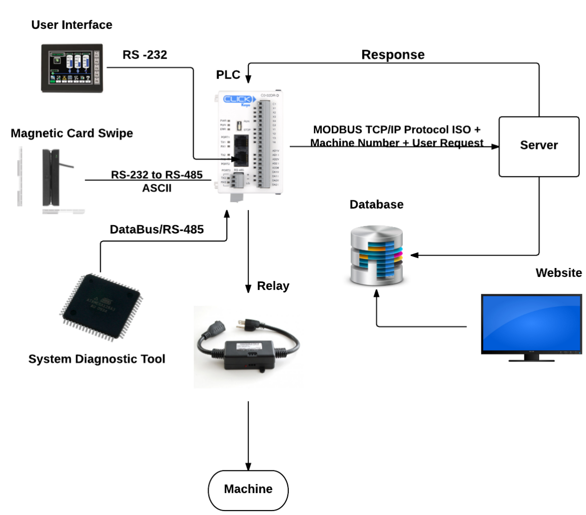
The Control system will be designed to cover a wide range of issues. One of the biggest challenges faced right now, is being able to schedule a device/machine in advance. Often enough, students or professors do not communicate with one another scheduling of when a machine will be used or when it has availability. Part of the Control system will be to enable all authorized users access to a website to schedule a specific time to use a machine. This will give the opportunity for students to plan experiments in a timelier manner and budget their time more efficiently. To go along with scheduling, no unauthorized user of equipment will be allowed to freely go into a room and use any machine. The system will create accountability for equipment use as well as any wear on a machine by indicating which user most frequently operated a given machine. The second largest motivation for a control system is to provide record of, and charge appropriately for, use of a device. Each machine in the clean room has ownership by a Professor or the school of Engineering. With the current system, there is no way to have documentation of who entered the clean room and who used a device other than by signing a sheet of paper. The Control System will provide the time that each user occupied a machine, the time a user scheduled the machine, and each time a user enters the Clean Room itself. With this information, the administrator will be able to accurately bill for use of materials and devices for all persons that are authorized access to the clean room.

The main motivation for implementing a dynamic control system into UCFs engineering clean rooms was dictated by the sponsor. In previous years, several senior design teams had attempted to implement a system to use for accountability and authorization for each machine. However, with some constraints in budget as well as constraints given by UCF engineering department, groups did not have success in creating a system that was sustainable and practical to use. Previous projects attempted to create a PCB design as the main unit to control all machine functionality. Relying on a single PCB design to be able to send power to relays for many machines, to be able to function with many timers running at the same time, to be able to communicate through any means of a website or database proved to be too much for a single processor or design.

## II. SYSTEM COMPONENTS

### A. System Overview

Fig. 1. Overview of System




The diagram given in Figure 1 shows the highest-level overview of the control system. This figure already assumes the user has first made a reservation via the website. The diagram below gives clarity to how the control system functions. When the user wants to interact with the system, he will first use the touch screen interface to use a machine. The interface will have multiple options for the user. If the user

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wants to login and use a machine, the interface will prompt the user to swipe his UCF ID using the magnetic card swipe. The information is then sent to the PLC (Programmable Logic Controller) which acts as the master in a master/slave configuration. The PLC packages the information together such as the users UCF ISO number, the machine requested for use, and the request type to the server. The server communicates with the database to give either permission or denial. With Permission, the user will receive a message on the interface indicating a successful login. If the user is denied, a packet of information will be transmitted to the interface that will give a general description to the user as to why he is denied access. Two examples of such permissions are the user is not authorized to use this machine, or the user did not schedule a reservation.

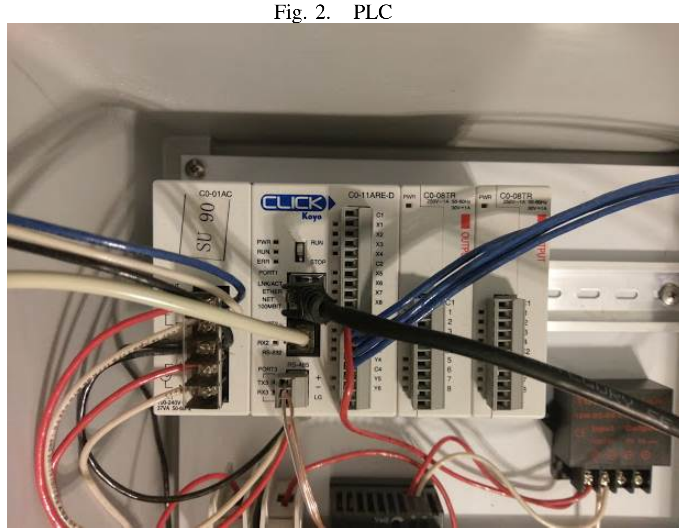
Once permission is granted, the PLC sends an enable high to the relay to turn on the selected machine. A timer is set by the PLC for the given time that the user scheduled the machine for. This information was part of the package of data sent from the database to the PLC responding to the request. If at any time, the user wishes to terminate experimentation early, he will be able to logoff and the time used will be sent from the PLC to the database to be recorded. If the user wishes to extend time, there will also be that option; provided no other scheduling conflicts. To run along parallel to the system is the system diagnostic tool which will connect to the PLC through an expansion of the PLC and through the RS-485 port. This tool will be designed to allow for quick access in case some error occurs when using the PLC. It should give administration the ability to determine which machines are in use and give the amount of time left on each in use. It should also be able to determine which machines are out of order, and should be able to indicate whether the PLC is function correctly. The diagnostic tool will have a smaller LCD display along with directional buttons to navigate through options.

### *B. PLC*

The PLC is a programmable logic controller that can be programmed according to the users needs and provides discrete as well as analog/digital data inputs and outputs typically in a modular configuration. This combined the elements of customizability and expandability of the ProXR Web Relay but did so at a lower cost that could be tailored according to the needs of the project. A basic PLC costs under 200 dollars and expansion modules as well as power supplies are typically under 100 dollars in the less powerful product lines that would suit our purposes perfectly.

The final product we researched is the Click Micro PLC line from Automation Direct. Automation Direct supplies a plethora of products that are used in various industries in order to automate processes, production lines and machinery. We chose the Click Micro due to its low cost, and modular expansion capabilities as well as the free software available to program the device. A base unit includes an Ethernet port for networking and communication, an RS-232 RJ-12 port for connecting compatible devices (in our case, we used

Fig. 2. PLC




this port for a touch screen interface), and a two-wire RS-485 port that will be used to receive the card swipe input data. An important part of our decision was the amount of compatible products available for the Click Micro PLC and the availability of those products. Automation Direct also makes the vast majority of its products available to order online so in the case of component failure, it is easy to get a replacement. All of these factors combined made Automation Direct our chose of supplier for the majority of the hardware for our project. Combined, the cost of the PLC base module, all power supplies, output expansion modules, touch screen interface, and other panel hardware came to about 1200 dollars for one complete system that can be installed in a laboratory.

Figure 2 shows the PLC in the center as well as the attached power supply on the left, and two 8-point relay output expansion blocks. This convenient ability to add on expansion blocks is important to our sponsor because it means user expandability is quick and easy.

### *C. Touch Screen*

Fig. 3. Touch Screen


Following our decision to use Automation Direct Click Micro PLCs, the choice for touch screen became simplified: we had several choices from Automation Direct that were compatible with the PLC we selected. We considered the 3 inch C-more Micro touch panel and it was a good fit for testing the system in the initial stages of prototyping, but the amount of information we wanted to give the user on one screen did not fit in the 128 x 64 pixel display. This led us to change to the 6 EA3-T6CL C-more micro panel.

The bigger touch panel afforded us several benefits such as a 320 x 240 pixel display, giving us more room to create various buttons, display instructions, and user feedback; full 32K color display to help with making certain parts of the user interface stand out; free programming software available for download; separate port for programming and communication with the PLC, making the programming and design much more convenient. Something we had to consider when choosing this panel was the power supply; the 3 panel was port powered through the PLC but the bigger 6 panel requires a separate +12-24 V power supply.

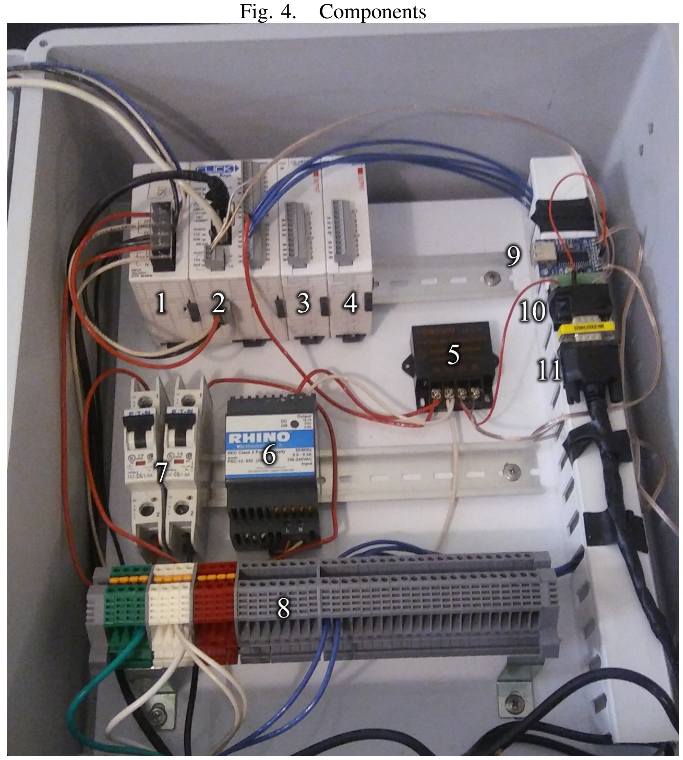
### D. Hardware

The system was envisioned as a single enclosure that contains all the necessary system hardware, excluding external machine relays connected by wire, as well as the relevant user interface components to be able to stand alone in the cleanroom without disrupting the environment in terms of space or accessibility. Towards this end, we went back to Automation Direct to find an enclosure that would satisfy our requirements. We settled on the Hubbell-Wiegmann enclosure model number HW-J161406CHQR. It is a hot compression-molded fiberglass enclosure with two metal latches that are compatible with padlocks and it can be mounted to the wall. The enclosure measures 16 tall x 14 wide x 6 deep, so when it is wall mounted it will be about the size of a medicine cabinet. With this enclosure, we were able to centralize most of the control hardware for the LCS including the PLC, relevant expansion blocks, two power supplies, two circuit breakers, terminal block strip with slot for every input and output, as well as the touch panel interface mounted in the door of the enclosure itself and the magnetic card swipe also mounted on the door. Most of the components in the panel are mounted to the backplane via three DIN rails that run horizontally and are in turn attached to the backplane.

This is an important design feature because it allows anyone who needs to service components convenient access to the entire hardware system. In order to service or replace a single component, it is easy to pull it off the DIN rail without any special tools. If the whole panel needs to be diagnosed, it only takes four screws to remove the backplane and all components attached to it and now the system can be placed on a diagnostics workbench. No proprietary or unique fasteners were used in the construction of the panel where it was possible to do so. Special thanks to the faculty and students of the UCF machine shop for helping cut out the hole in the panel door which we needed in order to mount the touch panel!

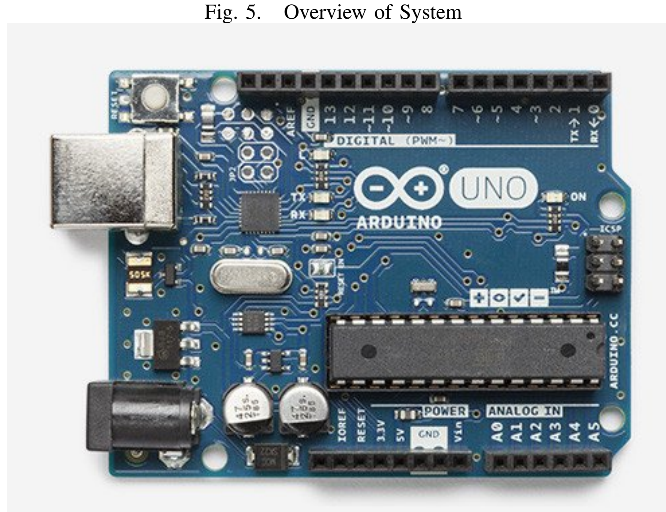
The components in figure 4 are as follows: 1. PLC power supply, 2 PLC main module, 3 Output expansion module 1, 4 Output expansion module 2, 5 12V DC to 5V DC converter, 6 120V AC to 12V DC converter, 7 6 A circuit breakers (x2), 8 Terminal block strip (green = ground, white = neutral, red = 120V, grey = I/O), 9 5V DC to 3V DC, converter, 10 DB9/D-SUB/Serial port to screw terminal pinout board, 11 9-pin serial connector plug leading to card swipe, 12 6 touch panel and monitor interface, 13 Card orientation instructions

Fig. 4. Components




### E. Raspberry Pi

Fig. 5. Overview of System




The Raspberry Pi and Arduino boards are perhaps the most well-known in engineering, computer science, and other tech circles. They provide almost limitless flexibility at a low cost that is attractive to those who are developing solutions on a budget and need a robust platform that they can configure to their specifications. However, the level of customization that is available and necessary to implement the LCS using one of these boards is too high for the purposes of our project. A specific requirement of our sponsor is that in case of component failure, the system should remain user-serviceable through a series of simple steps and the components that need to be replaced or repaired should be available for purchase by the user/system administrator. This requirement conflicts with the UCF senior design requirement that each group design a PCB that serves a central or important role in the overall project. By designing a custom PCB utilizing elements similar to the Raspberry Pi or Arduino, the system is no longer user-serviceable because in case of component failure, the whole board needs to be replaced and because it is a custom design, it needs to be special ordered from PCB manufacturers. Despite the appeal of this solution, restrictions in design and requirements on both the sponsor side and the senior design side prevented us from choosing this path in order to realize the LCS.

## III. SYSTEM ARCHITECTURE

### A. Hardware Design and Schematics

Efficiency and limiting power consumption is not a focus or intent when implementing the LCS. Nor does in factor into design constraints of the DT. While the notion of power efficiency and conservation is an important one that all engineers are faced with in design, our sponsors main concern is functionality and longevity which meant going with industry standards developed. Had an approach be taken to be more competitive with power consumption, different design decisions would have occurred. For example, with both chips the ATMega 328 and the MAX485 have an operating Voltage approximately 5 V. Texas Instruments microcontrollers and equivalent 485 chips have lower operating voltage with additional power save modes. The decision to use the Devices were ones of performance over power efficiency.

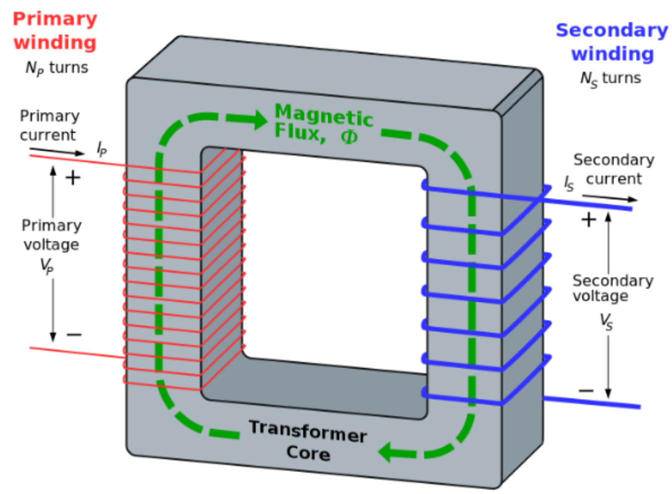
Fig. 6. Operating Voltages

| Device | Operating Voltage (V) | Current |
| --- | --- | --- |
| ATmega 328 | 4.5 – 5 .5 V | 5.5mA(idle) – 12mA(active) |
| MAX485 | 4.75 – 5.25 V | 120μA (unloaded) – 500μA (fully loaded) |
| Sainsmart LCD2004 | 5 V | 1.6 mA |

Table 12 lists all the operating voltages and currents to be used for the DT. This range of current for the ATMega 328 can be attributed to using different clock speeds for the chip. For instance, when the ATMega 328 is in Active mode, 1MHz, and Vcc = 2 V the maximum current consumption is 0.5 mA versus Active mode, 8MHz, and Vcc = 5V the maximum current is around 12 mA. This is a large difference in just adjusting the clock frequency of the microcontroller. Clearly we can see the frequency is a function of not just current, but also voltage. A depiction of frequency versus voltage is given in the section that outlines adding an external crystal.

With power efficiency not a concern, there is still options with the ATmega 328 to put in various sleep modes to enabling unused modules to be shut down in the MCU. A Brown-out Detector (BOD), if enabled, monitors the power supply voltage during sleep periods that also contribute to saving power consumption. Six different sleep modes exist for the ATmega 328, as well as an Idle Mode, ADC Noise Reduction Mode, and Power-Down Mode. If time permits these options will be considered for greater efficiency when using the DT.

Fig. 7. Transformer




The transformer is the beginning component used when building a Power supply. A transformer was chosen over a switching system for several reasons. A transformer costs much less than a switching system. It has relatively simple circuitry, and low noise. Whereas, the switching system has significantly more complex circuitry and there exists some switching noise. The transformer does have a few short comings, namely heat dissipation and lower efficiency. Figure 41 gives the fundamental theory behind the transformer of interest; the step-down transformer. Equation 1 dictates this basic principle from electromagnetic field theory to step down from primary to secondary voltage.

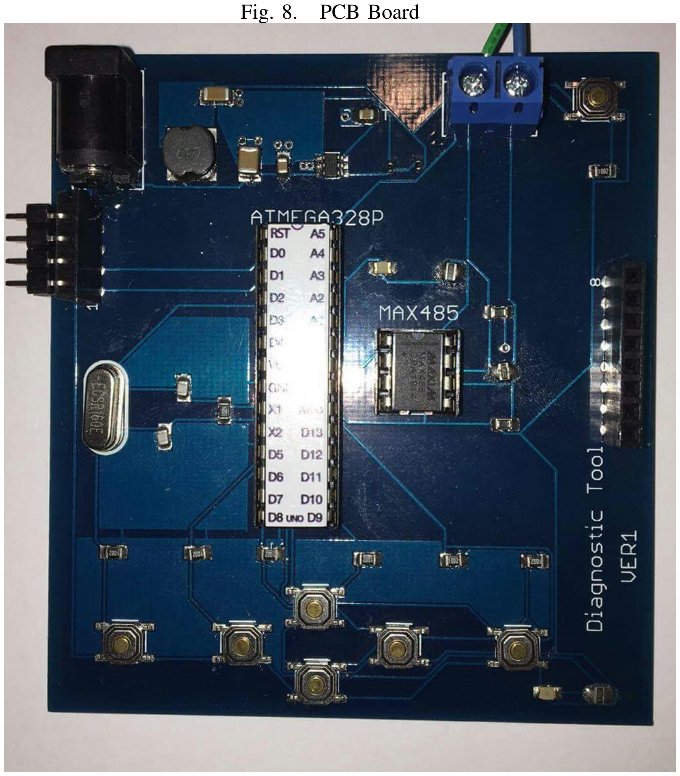
Two more factors to determine a suitable transformer is the type, and what kind of mounting method to use. Because we have decided to use the full wave rectifier for part of the AC to DC signal process, a central tapped transformer is the only option. Mounting options will be decided based primarily on cost. There is not too much concern for size considering it will power the DT which is an attachable unit to the LCS. Some options still under consideration are the PCB, Snap in, Surface Mount, and Through Hole.

### B. Diagnostic Tool and PCB

The Diagnostic tool is meant to run parallel to the control system. It will assist in quickly diagnosing any malfunctions with the system and provide administration quick access to the PLC. The goal of the DT is to be able to communicate immediately with the PLC through an 8-point input module, and receive communication through Port 3 via RS-485.

In order to make sure the card swipe and diagnostic tool can be connected to the PLC simultaneously and not require the user to connect anything to the panel in order to use the diagnostic tool, we will implement a pass-through system. The card reader will be connected to the diagnostic tool and by default, the diagnostic tool will pass the signal through itself and onto the PLC which will then read the card swipes under normal use. If the diagnostic tool is activated, the PLC will know via the 8-point input module, and will know to send data out of the RS-485 port rather than receive data. The diagnostic tool itself will also switch over to receive the data from the PLC and display it, rather than allowing the card swipe data to pass into the PLC

Fig. 8. PCB Board




One of the most fundamental and overlook aspects of design is Power requirements of the system. Even with the DT being a tool that runs parallel to the control system, different components of the system require varying voltages and/or currents. When researching, several different types of basic AC to DC conversion options are available. Since this is not critical to design, we will investigate various options, and with time permitting, have full implementation.

The LM5023 AC-DC Quasi-Resonant Current was initially considered as an option for design. After viewing documentation from Texas Instruments Datasheet, even the most common applications for VAC -VDC conversion seemed complicated in design and components. With budgeting for the DT from funds outside of the sponsors budget, we felt that although benefits do arise from using this configuration, it would not be feasible to implement for the Diagnostic Tool.

A popular option for our design from 120 VAC outlet to a 12 VDC implements a simple design and far less components than that of LM5023. The voltage first needs to be converted from VAC to VDC. It will then need to be further stepped down to 12VDC. From the source (wall), a step-down transformer will be used. Once the voltage is stepped down it is fed through a bridge rectifier composed of four diodes. Using bypass capacitors for limiting ripple, the signal is then transmitted through a 12-volt linear regulator to accurately maintain a 12-volt DC signal. Figure 14 gives a block diagram of progression from outlet to 12 Volt DC signal.

### C. *Communications*

A final layer of communication will be utilized to take data from PLC and use that data in relation to a database of information. This additional Application Layer will connect the local PC with a Server Database in order to effectively establish working parameters to the PLC.

The final result of the network will allow the data to be sent from PLC to the PC. From the PC this data will then be compared to data in the database on the Server to formulate a response to PLC. This response will then be sent back to PLC.

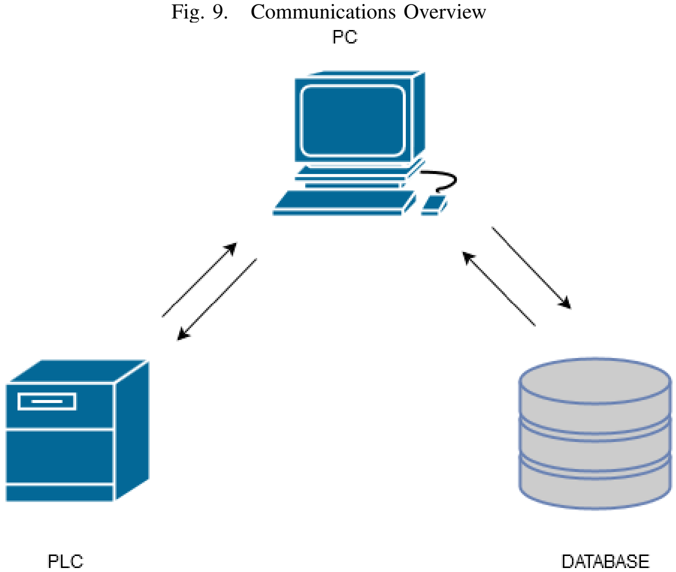
The TCP layer effectively provides the communication between PC and PLC. This protocol will provide for error checking and synchronization of the communication between the PC and PLC. This is done by using a header. The communication is performed by opening a socket.The standard port number for the MODBUS protocol is port number 502.

For transmission of data the most important part of the TCP transmission is the data section. This section will include all the data that is sent and received through the MODBUS protocol between the PC and PLC. There are many different ways to send this data but for implementation of the MODBUS protocol the most intuitive way will be through the use of a byte array buffer that will be used to transmit and receive information through the use of bytes that are stored in a dynamically allocated buffer.

The server is effectively always listening for the requests made by the client. These requests are then handled by the server and then result of the request is then returned to the client.

Once data is received from the PLC, it is parsed through the MODBUS protocol to identify specific information. This information is then compared to information that is stored in a database. After the comparison is made with the database data, then a response to the PLC can be formalized. Information from the database will be sent back to the PC. The PC will then interpret this data through logic to determine a response to the PLC. The information being stored in the database, such as ISO numbers, machine IDs, and scheduling information, are used to send a response to the PLC. This is the first series of communication between the PC and database. After sending the information to the PLC, the PC will await for further responses from the PLC. After these responses are received the PC will once again interact with the database. The first interaction with the database can be thought of as reading information from the database.

Fig. 9. Communications Overview



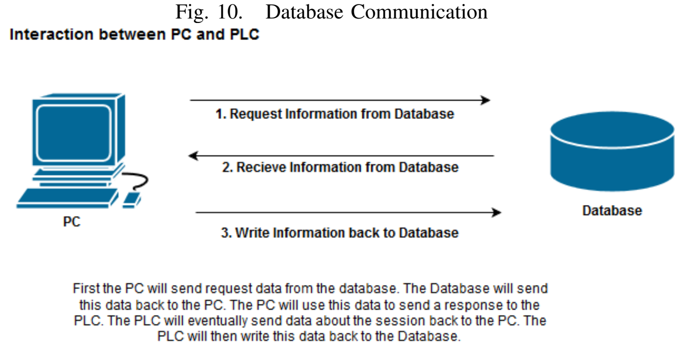

The second interaction with the database consists of writing information to the database. Once a user has finished using a machine in the clean room, the PLC will send a response to the PC letting the PC know that a user is finished using the machine. This data will be sent to the PC through the MODBUS protocol. The PC will then calculate the total time that a user used a machine and will write that information back the database. The database thus will be able to keep full logs on the usage of each machine. These logs will be able to store information such as all machine start and stop times, and all users who logged into a machine. The logs can then be used to perform any audit of machine use if need be.

First the PC will send a request for data from the database. Next, the database will send this data back to the PC. Then the PC will use this data to formulate and send a response to the PLC. The PLC will eventually send data about the session back to the PC. Then the PC will then update information on the database

A simplified example of communication between the PLC and database would be determining if a user is allowed to use a machine. Once the user has scheduled an appointment to use a machine on the website, this appointment will be stored in the database. The user will scan his UCF ID at the magnetic card reader terminal while selecting the appropriate machine number. The users ISO and machine number will be sent to the PC from the PLC through the MODBUS protocol. These will be stored in local variables. The PC will then connect to the database through the driver. The PC will send the database a request for the scheduled time that user made for that specific machine number under his ISO number. The database will then send the PC back the scheduled time. The PC will check if the current time is with the scheduled time. Once this check is complete the PC will send a message to the PLC with the total time to turn on the specific machine. The user will then use the machine until his time is up or the user logs out. The PLC will then send a message to the PC notifying the PC that the user is finished. The PC will then calculate the total time used by the user on the specific machine and store it in a variable. The PC will then send the total time the user was on a specific machine to be written into the database. This will conclude the communication.

An important aspect of receiving and sending information from the communications is to have checks in place along the transmission of data to make sure the data being received is correct. The main points along the path of receiving data to take note of are the data received from the PLC and the data received from the database. There are certain checks that must be implemented to make sure that the data received is the correct data that is expected. Otherwise the program will send incorrect data. In the transmission of data the first transmission is the information received from the PLC.

Fig. 10. Database Communication




### D. *Webserver*

PHP is a server-side programming language widely used in the development of web applications. It is a powerful object oriented language that can be used to create dynamic web pages. PHP is commonly supported and there are a great deal of resources for developers. PHP natively support MySQL database queries, so an external library would not be necessary to access user information stored in a database. PHP supports DateTime functions. DateTime is a format standard used by software and databases to store exact time information and is a critical aspect of creating a reservation system. Sessions and cookies can be managed in PHP applications which enable user authentication, a vital element of a login system.

PHP sessions enable user tracking through server variables. When a user access our website through the login component, session variables for that user are created. Using these variables, the server-side PHP code can identify who the user is and what they are doing on the website. Session variables are an important aspect of web development, and because sessions are supported by PHP, we will be using session variables to a great extent in our system. User login, authentication, reservations and invoices will all incorporate session variables in their algorithms.

WordPress is a content management system based on PHP and MySQL. It is one of the most popular website creation tools available and can be used to develop all types of websites and web applications. WordPress is popular because it is easy to use, free and open-source. WordPress comes with a variety of themes which can be used to give a website a consistent template. Themes are a big part of WordPress. The user community is highly activity, and thousands of themes can be downloaded and included in your WordPress installation. Packages are available for purchase which add additional themes and features.UCF uses WordPress to format and template their websites. A variety of UCF web themes are available for download off the UCF GitHub repository.

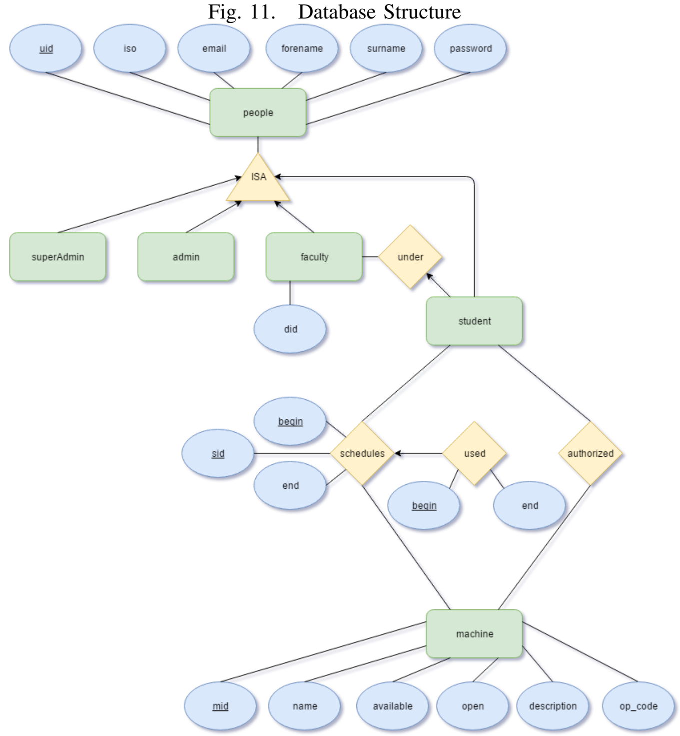
The Document Object Model (or DOM) is an application programming interface (API) for HTML documents. The concept provides a structure for HTML documents - a hierarchy or tree of components - that allow for document access and manipulation. For example, a JavaScript developer with an understanding of the Document Object Model will be able to manipulate elements of the web page after having already been loaded into the users browser. This is how websites like Facebook and Google allow for instant messaging between users: a client-side application like JavaScript is accessing a database and manipulating the HTML of the webpage without having to refresh the page. The Document Object Model can be used in a wide variety of programming applications.

Bootstrap, a CSS library that will be used in our system, implements the Document Object Model. Bootstrap is a free, open-source, CSS, HTML and JavaScript library that is commonly used in modern web applications. It provides a sleek, simplistic design for common HTML elements and mobile friendly customization options. The Bootstrap resources website contains useful information for developers to get up and started with Bootstrap quickly. Bootstrap will help to reduce the development process by minimizing the amount of CSS code the development team will have to produce. Most of the web application styling can be accomplished through an understanding of Bootstrap classes and components.

MySQL is the most widely used database management system in the world. It is full of features and relatively simple to use. MySQL supports reliable transactions, a critical element of a reservation system which enables multiple users to reserve time slots without conflicts. MySQL supports a variety of data types, including integers, single and double precision values, varchars, blobs, date-time and much more. MySQL has support for user management which enables custom user permissions. MySQL enables concurrent database access allowing multiple users to interact with the database simultaneously. Most importantly, the UCF Tech Support can provide students with a MySQL database on a UCF server. Due to its native integration into PHP, MySQL and PHP would be an efficient combination of server-side programming language and database system.

The University of Central Florida Tech Support team can

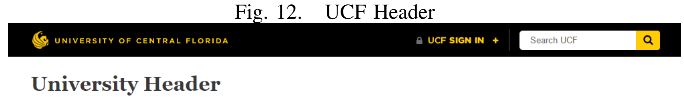
Fig. 11. Database Structure




provide students access to a server on the UCF network. The cleanroom reservation system is designed to be integrated into the UCF software infrastructure and will need to be installed onto a UCF server. The UCF server environment provided to the cleanroom reservation system team will share similarities with the XAMPP environment used to develop and design the software.

Obtaining a server on the UCF network is an important aspect of our project. The UCF network is capable of running our backend server code, our database, will provide us with a layer of security under the Shibboleth (Federated Identity) login screen, and will be easiest to maintain in the long run. A server on the UCF network will also mean that we wont be having to host the website and database on a computer in the cleanroom laboratory, which has very limited space availability.

Fig. 12. UCF Header




The UCF Tech Support department located in the Harris Corp Engineering building maintains the UCF network and grant users with server space. Hosting an application on the UCF network is a delicate process. UCF takes security very seriously, and handing out server space to undergraduate students is typically not something they do. There have been only a handful of cases were undergraduate students were granted server space for their senior design projects. Among those rare cases, even fewer applications were allowed to continue running on the network after the senior design process was completed.

Intially we wanted to implement the Shibboleth security layer for the cleanroom portal login, but instead decided to design our own login component. Developing our own login mechanism allows us to design a system tailored exactly to the needs of the cleanroom staff. For example, limiting account creation to pre-approved emails. One concern was that developing our own system doesn't take advantage of the Shibboleth security features. The Tech Support group grants server space with limited permissions. In the event that our website is hacked, damage will be limited to the resources we have permission to modify. UCF takes minimal risk while providing us with the server resources that we are requesting.

The server is accessed via an ssh link. The Tech Support group provided us with the login credentials that we will need to sign into the network. From there, we will have access to a home directory which hosts our PHP web material. Files are uploaded to the server via FTP. Similarly, a database has been created and is accessible from our directory. For ease of use, Tech Support has recommended ssh tools like Cyberduck to make managing our server resources simpler.

## IV. CONCLUSION

This project has incorporated skills learned from electrical engineering, computer engineering, and computer science. Many levels of abstraction have been covered in this project. The design has drawn from the concepts of elementary electrical components such as resistors and capacitors, to high level programming for design and implementation of websites and databases. We have applied what we learned in our classes, but most importantly we have each contributed to the project as individuals in our preferred field of study. The skills learned and applied during the making of this project have been transferable to each group members future area of study and/or career. We have all learned valuable lesson in coming together with ideas, and working together with our ideas to complete a finished product.

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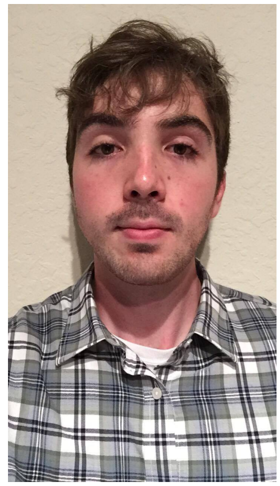
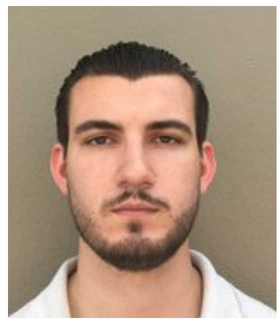
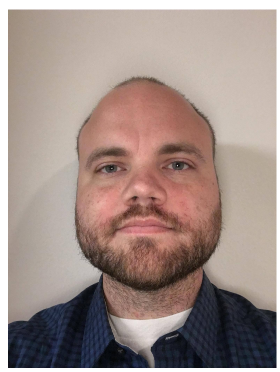


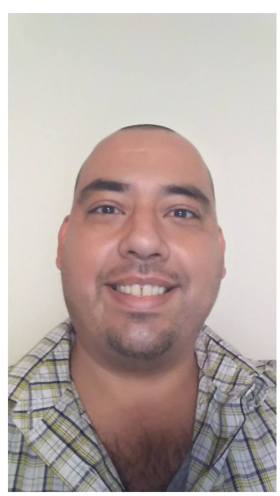
13. Jimmy Ossa is a senior studying Computer Engineering at the University of Central Florida. He plans to graduate in May 2017 with a BSCpE. Jimmy is interested in Web Development, Communication Networks, and Database administration. Jimmy will be beginning his career as a software engineer. He later plans to pursue a graduate degree in the field of computer networking.



14. Anatoly Kozorezov is a senior studying Electrical Engineering at the University of Central Florida. He plans to graduate in May 2017 with a BSEE. His areas of interest include embedded programming, computer hardware/software, and circuit design.



15. Aaron Borgess is a senior studying Electrical Engineering at the University of Central Florida. He plans to graduate in May 2017. He plans after are to continue with graduate school, with an emphasis on communications and signal processing, while entering the field of engineering.



16. Miguel Aleksich Ortiz is a senior studying Computer Engineering at the University of Central Florida. He plans to graduate in May 2017 with a BSCpE. He is currently working at Lockheed Martin and plans to continue with graduate school, with an emphasis in embedded programming.