Team 22 –Automated High volume Bearing Bore Gage

Final Report

Deliverable 3

Team Members:

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Seth Norman
Christopher Proffett

Sponsor:

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Dr. Cartes

Instructors:

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12-6-2013

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Abstract

The objective of this project is to improve the out of date bearing bore gage system used by Koyo Bearings. This improvement must advance the user interface while maintaining the quality of the measuring device and the sampling rate. The improvement should also allow for the communication of each gage to a central terminal. This will allow for multiple systems to be monitored from a single device. We have researched the inner workings of the machine and its components. We have also talked to Koyo Bearings and decided that they are pleased with the existing air transducers set up using LVDTs and would like us only to update the electronics and interface. We have researched interfacing options and have come up with a design implementing a signal conditioner from the LVDT to the PLC and to a CPU. The CPU will output bearing information to the new display. A design proposal and bill of materials has been submitted to Koyo Bearings and we are currently waiting on feedback.

Human Resources

Eric Allgeier - He has the responsibility of displaying and organizing any group information on a website. He will also need to keep record of all the deliverables, meeting minutes, personal information, critical dates or other records of information that is critical to the project. The information will need to be well organized and easily accessible to all members or inquiring parties.

Matthew Boler - He is responsible for ensuring that all deadlines are met. He is to keep track of all deliverables and assign tasks for each deliverable. He will be the one to turn in all assignments, whether digital or physical. He is also responsible for overseeing and delegating the mechanical aspects of the design.

Kevin Flemming - He will be in charge of building models and machining any parts that are needed. He will have primary access to the bearing bore gauge machine that is located on campus. Also, he will be in charge of the group's finances and will coordinate purchases with Koyo Bearing.

Seth Norman - The role of project manager is to delegate work amongst the team members accordingly to their qualification. He should oversee all work being done on the project and make sure it is being done correctly and in a timely fashion. Also, he will help coordinate with other team members on a realistic timeline for the project, so the team can set mini-goals throughout the project.

Christopher Proffett - It is his primary responsibility to take care of all scheduling for meetings on a weekly and biweekly basis. He is also in charge of communicating with all of our outside advisors and scheduling when the team can meet with them on a consistent basis. He will be in charge of contact with our sponsor, Mr. Robert Potts, and will decide when, where, and how often he would like to meet with us. He is in charge of sending memos to everyone reminding them when and where to be for all meetings.

Robert Potts - He is the team's contact at Koyo Bearings. All of our communication with their company goes through him.

Project Overview

Problem statement

The objective of this project is to improve the out-of-date bearing bore gage system used by Koyo Bearings. This improvement must advance the user interface while maintaining the quality of the measuring device and the sampling rate. The improvement should also allow for the communication of each bearing bore gage device to a central terminal. This will allow for multiple systems to be monitored from a single device.

Project Objectives

The main goal for this protect is to retrofit the bearing gauge testing console with a new computer, operating system, and display. In addition, the machine should later be able to connect to the network at the Koyo plant. Projected date of completion is May 2014.

Plan for the Fall Semester:

1. Research the inner workings of the machine and components.
2. Research for a heavy duty industrial rated computer and display.
3. Research interfacing options.
4. Use a Decision Matrix to choose best design.
5. Make bill of material for all the parts needed to complete this task.
6. Submit our design to Koyo Bearings.
7. Quote and order all parts needed for the design.
8. Create Project Objectives for Spring Semester.

Overall Methodology

The designing of this retrofit will be broken down into multiple phase. The first phase will be to study the behavior/controls of the air transducers. Then there will be a group decision, consisting of the team members and project advisors, to see if there is any need to replace the transducers with a different style of pneumatic transducer. Phase two will be to research the new heavy duty industrial rated computer and display. Phase three will be to design a complete working system, then submit the design to Koyo Bearing. Phase four will be to make a bill of material and then order the parts needed. Phase five will be to make scope of work for the spring semester.

Project Constraints

- $2,000 budget provided by Koyo Bearing (negotiable)
- All purchases are to be made through Koyo Bearing
- Design must be finalized by the end of Fall semester
- Parts ordered at end of Fall semester
- Assembly, coding, and testing must be completed by April

Design and Analysis

Function Analysis

The Bearing Bore Gage is comprised of three main sections. The first section is mechanical in nature; it locks the bearing in the testing platform, inserts the pneumatic probe, and allows bearings within the tolerance to pass while dumping bearings outside of the tolerance. This is accomplished through the use of pneumatic pistons; when the pistons are activated, they cause linear motion which is the input of a mechanism. Several piston/mechanism combinations are used in conjunction with one another to achieve the desired bearing path.

The second section of the device is the mechanical/electrical interface. This is composed of the LVDTs (Linear variable differential transformer), figure 1, pneumatic solenoids, and pneumatic cylinders. The LVDTs take the pressure from the pneumatic probe and converts it into an electrical signal, in this case, a differential voltage. The LVDT operates by utilizing three solenoids and a ferromagnetic core. The central solenoid is excited by an external, alternating, voltage source. This induces a current, and therefore a voltage, in the other two solenoids. The placement of the core in the LVDT alters the induced voltage in the secondary solenoids. The core's placement inside the LVDT is a direct result of the pressure from the pneumatic probe. The LVDT outputs the voltages from the secondary solenoids; the difference between these voltages can then be analyzed to give the bearing's bore size.

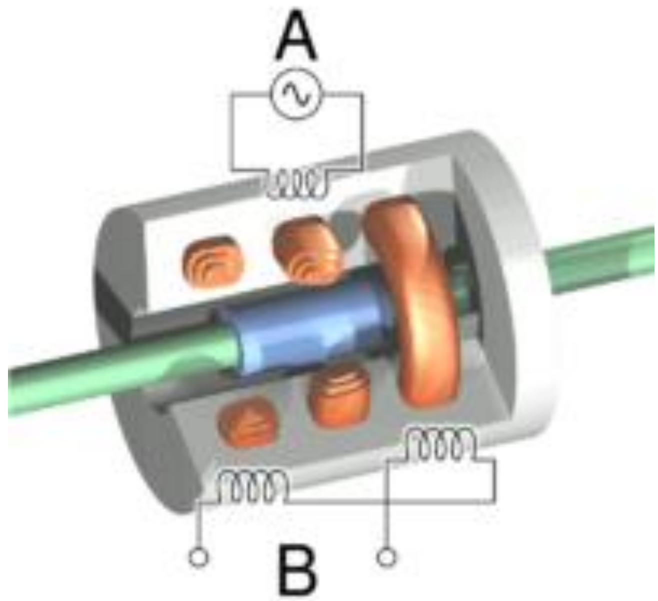


Figure 1: Schematic of an LVDT

The pneumatic solenoids, figure 2, take an electrical signal from the PLC (Programmable Logic Controller) and produces a pressure to actuate a mechanism. This device uses a solenoid as a valve. When a current flows through the solenoid, it creates a magnetic field which forces the magnetic core to open. When the valve is open, it allows the pressurized air to flow to the pneumatic piston. When the valve is closed, the pressurized air is halted. In this case, a secondary opening must be made to release the pressure; this is often done by combining two valves: one valve allows the line to be pressurized, the other acts as a pressure release valve.

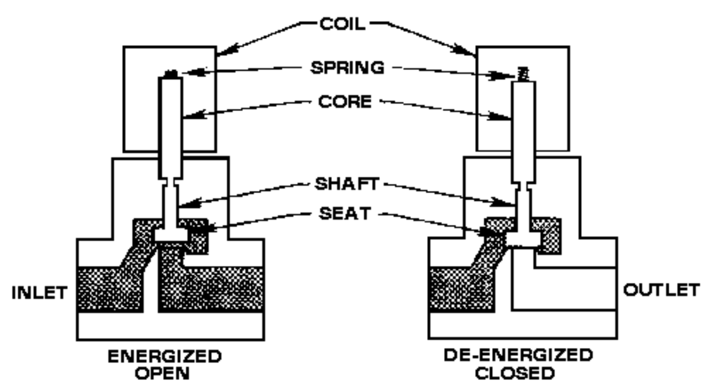


Figure 2: Schematic of a pneumatic actuator

The final section of the device is electrical. In this section, the electrical signals from the LVDTs are conditioned and analyzed. The information contained in the signals must be transmitted to the PLC for a decision on tolerances. This must be then transmitted to the linear actuators in order to pass or fail the bearing. The LVDT signal shall also be transmitted to the CPU (Central Processing Unit). The CPU will record the past bearing values and control the GUI (graphic user interface). A Proximity switch must also be used to indicate when a bearing is present.

Design concepts

Koyo bearing has expressed their pleasure with the current mechanical system in place and their concerns with the electrical system. Because of this, we have been instructed to update the GUI and networking components only. This means that we will be keeping the current LVDTs and pneumatic actuators while updating the CPU, PLC, display, and user input controls. Therefore, the concepts listed below are for the electrical section described above.

Each concept that was created is based off of the same template, which will be described now; the differences between each concept will be explained in the sections below.

The PLC receives a signal from the Proximity Switch which tells the PLC that a bearing is present. The PLC will first command the actuators to lock the bearing in the testing apparatus and insert the pneumatic probe. The LVDT outputs a signal which gets transmitted to the Ethernet switch and PLC. By comparing the LVDT signal to the allowable range, the PLC will send signals to the pneumatic actuators which will send the bearing to either the pass or fail bin. The Ethernet switch will allow Koyo Bearing to communicate with the CPU. When the CPU is not communicating with Koyo bearing, it will be receiving the signal from the LVDT. The CPU will also communicate with the GUI which allows the user to see relevant information and input commands.

Concept 1: PC-104

The first design concept that we created utilized a PC-104 board and the CPU. Figure 3 shows the electrical layout in block diagram form. In this configuration, the LVDT signal is read by the PC-104 board. This board interprets the signal and forwards the information to the switch and PLC.

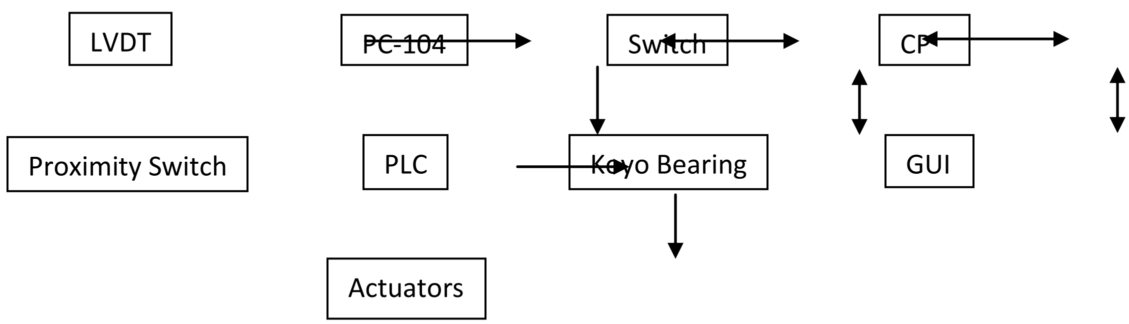


Figure 3: Communication Diagram of Concept 1

Concept 2: SC and PC-104

The second design concept utilizes a PC-104 board in conjunction with a signal conditioning module (SC). Figure 4, below, shows the electrical layout. In this configuration, the LVDT signal is send to the signal conditioning module. A clean signal is then forwarded to the PC-104 board which forwards the signal to the switch and PLC. The signal conditioner also acts as an amplifier; LVDTs usually produce a small differential voltage on the scale of millivolts.

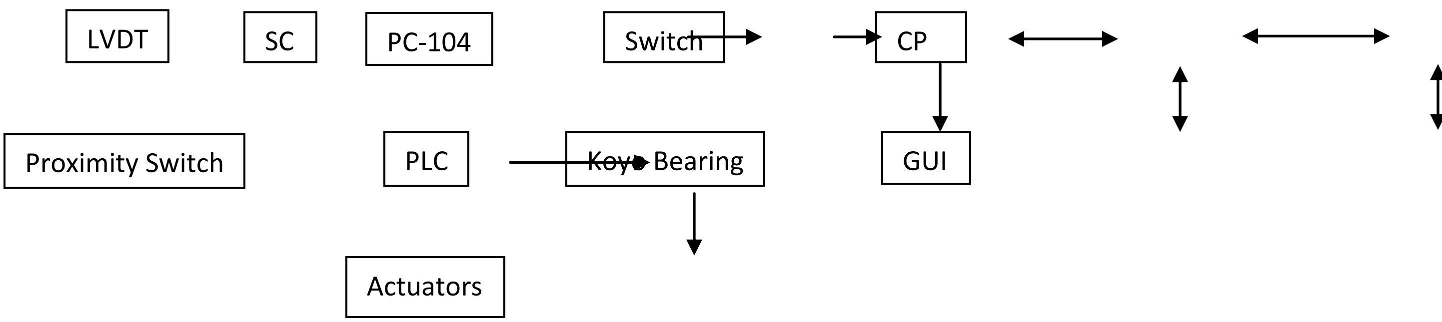


Figure 4: Communication Diagram of Concept 2

Concept 3: SC

The third design concept uses only a signal conditioning module, seen in figure 5. In this design, the LVDT signal is filtered through the SC and sent directly to the switch and PLC, bypassing the PC-104 board from design concept 2. This design is a result of research in the area of signal conditioners. Several signal conditioners are able to be programmed or tolerances. They can then export a logic high or low signal indicating whether the measurement was within specifications.

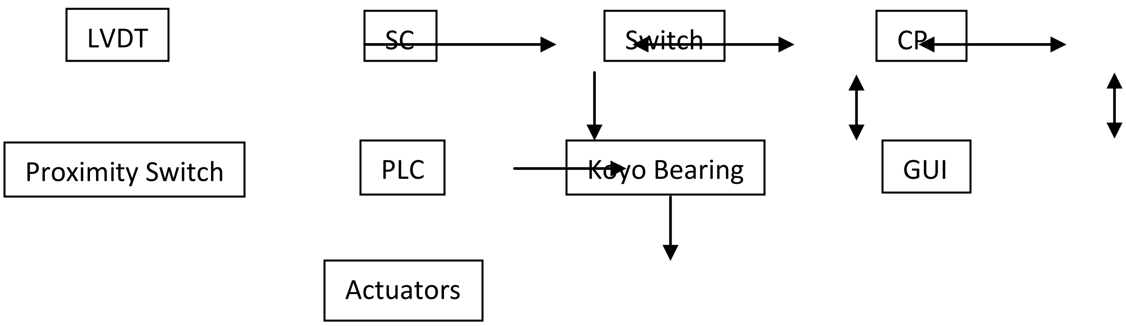


Figure 5: Communication Diagram of Concept 3

Concept 4: SC and no Switch

The last design concept, figure 6, differs from the previous one in the networking section; instead of using an Ethernet switch to prioritize communication between the CPU, SC, and Koyo's plant, the CPU talks directly with both. This can only be accomplished if the CPU has multiple RJ-45 ports.

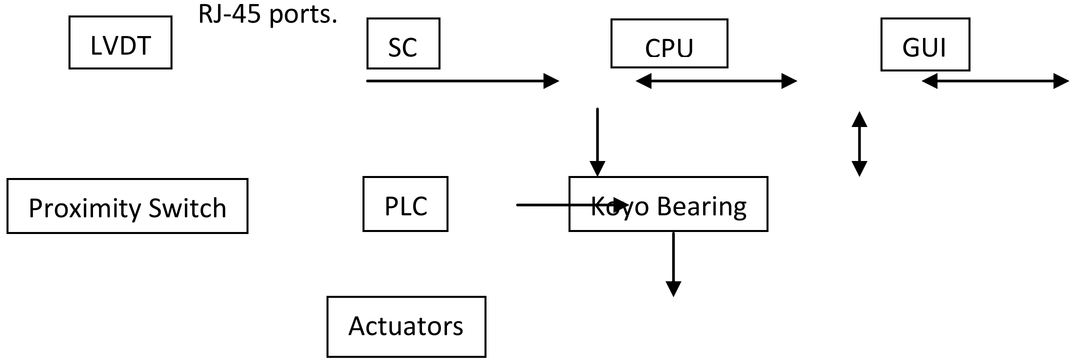


Figure 6: Communication Diagram of Concept 4

Electronic Components

CPU

A Raspberry Pi Model B was found to have all of the capabilities that were required of the CPU. It contained an RJ-45 port, two USB ports, and an HDMI port. Further research into other CPUs was halted when Koyo Bearing informed us that they are already in possession of an ASUS micro ATX. This board is much faster and has more ports than the Raspberry Pi and should perform all necessary tasks. The use of this component will be explained in the control section.

Switch

Because both the signal condition, or PC-104 board, and Koyo's plant must be able to communicate with the CPU, a switch must be implemented. An Ethernet switch provides a simple means of achieving this communication junction. Table 1 shows the relevant technical specification of the possible Ethernet switches. All of these are DIN rail mountable to allow for easy instillation and replacement.

Table 1: Relevant Specifications on possible Ethernet switches

Ethernet Switch	Cost	Number of Ports	Speed	Power Consumption	MTBF
N-T1005TX	$288.00	5	10/100/1000 Mbps	36 Watt	2,000,000 hr.
EISK5-GT	$148.00	5	10/100/1000 Mbps	3 Watt	N/A
IES5100	$77.24	5	10/100 Mbps	2.4 Watt	1,677,807 hr.

Power Supply

The electrical devices must be powered in some manner. Because the devices being considered operate on a DC voltage, the 120VAC signal provided by Koyo's plant must be modified. The output power will be determined by the other components in use. For convenience, all devices will run off of the same 24V DC signal. Table 2 is a compilation of possible power supplies. Each power supply runs off of 120VAC at 60Hz which is supplied by Koyo Bearing. They are also DIN rail mountable to allow for easy installation and replacement.

Table 2: Relevant specifications on possible power supplies

Power Supply	Cost	Output Voltage	Output Power	Housing	Max Current	MTBF
PSB24-060-P	$28.00	24 VDC	60 Watts	Plastic	2.5 Amp	>800,000 hr.
PS24-050D	$99.00	24 VDC	50 Watts	Metal	2.0 Amp	2,992,000 hr.
1769-PA4	N/A	24 VDC	48 Watts	Metal	2.0 Amp	N/A

Monitor

A monitor is required to display relevant information to the user. By selecting a touch screen, it will also act as the operators input. The previous year's team has recommended the FPM-5191G-X0AE. This is a 19" touchscreen HD LCD display. It connects to the CPU via USB and HDMI cables. Due to cost constraints and its large size, this monitor will not be used.

Existing Components

PLC (Programmable Logical Controller)

The existing PLC will need to be reprogramed to accept the signal coming from the LVDT. The LVDT will be connected to a signal conditioner. The signal conditioner will connect to the PLC with a single digital signal that is normally closed. Therefore, the PLC will have a nested logical algorithm that is controlled by signal coming from the signal conditioner. Once the logical algorithm has been processed by the PLC, the PLC will send a command to the pneumatic linear actuators to either accept or denied bearing, depending on the size tolerance of the bearing.

The existing program on the PLC is not compatible with the communication system desired. Therefore a new PLC is required.

New Components

Signal Conditioner

The signal conditioner will need to be configured to work with LVDT inside of the air transducer. The LVDT works on a differential voltage between the secondary coils. The difference between the voltages will give the size of bore on the inner diameter of the bearing. The signal conditioner will need to be calibrated to accept the minimum to maximum allowable size of the bearing. In the case where the bearing is between the minimum and maximum range, the signal conditioner will be programmed to send a low logic flag to the PLC. When the LVDT is out of range, the signal conditioner will send high logical flag to the PLC.

The signal conditioner will also need to be programed to send data to the new CPU. The data coming from signal conditioner will be stored in CPU for a history of accepted and denied bearing, so the Koyo plant can have data on the efficiency of their lathes and tooling.

CPU (Central Processing Unit)

The CPU will be used in this design to store data coming from signal conditioner. This data will be used to display a histogram to the operator of the machine and to the operator of the Koyo plant. Also, the CPU will be used to calibrate the signal conditioner for the minimum and maximum range of the bearing bore size. Advance Micro Controls INC., the makers of the signal conditioner, already have a program that will load on the CPU and be used for calibrating the signal conditioner. A program will need to be written to display the current histogram of the machine. Also in this program there will be a parts counter. Which displays the number of accepted and rejected bearing during an eight hour shift. Also, the program will warn the operator when the tooling inside their lathe needs to be changed.

Evaluation of Designs

In our final design we ended up choosing concept 3. We chose this because it is the simplest and most robust design. Design 3 gives us the least amount of components that are required for the machine to function. This keeps cost as low as possible and it keeps the overall design simple so there is less of a chance for component failure. We made one edit to design 3, it was decided that we would need a router instead of just an Ethernet switch. This is needed to keep the internal IP address separate from the Koyo network IP address. This is important for smooth networking between the machine and Koyo bearings factory network. Below, in table 3, is a simple decision matrix that was used to help us determine the most efficient design for this machine.

Table 3: Decision Matrix

	Cost	Complexity	Durability	Total
Design 1	7	6	7	20
Design 2	8	7	7	22
Design 3	9	10	8	27
Design 4	10	10	4	24

Component Selection

Using the chosen design, components were selected based on price, reliability, and size. Table 4 contains the bill of materials required to implement our design choice; those items marked with * are being provided by Koyo Bearings. It was their decision to use an Allen Bradley PLC due to its reliability even though the software is expensive.

Table 4: Bill of materials

Device	Part Number	Unit Price ($)	Quantity	Price ($)
CPU	LENOVO ThinkCentre M92p	*	1	*
PLC - Chassis	1746-A4	*	1	*
PLC – CPU/Ethernet Module	1746	*	1	*
PLC – Input Module AC	1746-IA16	*	1	*
PLC – Output Module DC	1746-OA16	*	1	*
PLC - Software	RSLogix 500	2050.00	1	2050.00
Signal Conditioner	ANR2	895.00	2	1790.00
Power Supply 24V	PSB24-060-P	28.00	1	28.00
Power Supply 12V	PSB12-060	37.25	1	37.25
Router	CTR-Link EIPR-E	299.00	1	299.00
Monitor	ELO 1537L	527.00	1	527.00
Circuit Breakers	QUO110	30.65	1	30.65
Misc. (DIN Rail…)	TBD	TBD	TBD	~100.00
Total			13	$4861.90

Electrical and Mechanical Layout

Several CAD drawings have been created to depict the layout of the housing. These include three electrical layouts of the communication, power, and logic, as well as two drawing of the component layout geometrically inside the housing cabinet. All of these can be found in the Appendix.

Programming Needs and Control

RSLogix 500 will be used to program the PLC. In order to test logic we will first create a test bed on which our logic will be tested. Once the code passes, we will then implement it on the PLC. We will be using Quincy, an open source programming software, to configure the GUI. The CPU will run on Windows 8 to utilize its touch screen capabilities.

Risk and Reliability

In the design of this product, we chose components with MTBF rates that are high enough so that Koyo will not have to worry about component failures in the foreseeable future. All wires will be heat shrunk and bundled together in an organized fashion in order to prevent any failures in the wiring. The machine is sampling a bearing once per six seconds; with such a low frequency, overheating should not be an issue. So far the pneumatic actuators on the machine have ran at 100 percent accuracy in measurements and since we are not making any changes to the pneumatic actuators, we expect to retain the 100 percent accuracy rate.

Manufacturing Recommendations

For this report we have attached all schematic and CAD drawings of the proposed electrical modules and mechanical designs in the appendix in the back. The first plan of action to manufacture this machine is to obtain all components and produce a test bench that will utilize all the logical functions of this machine before the machine is assembled. To produce this test bench we will be wiring a set of manual switches to replicate the inputs to the machine and lights to represent the outputs from the PLC. With all the inputs and outputs simulated we can program the PLC for the desired outputs without risking any damage to the machine. To program the touch screen we will be using Quincy visual programming software to establish all touch selection and data display. The machine has a home menu with various screens that may be desired by the operator. All menu options and statistical analysis equations are provided in detail in the current user's manual. This organization of the software will be replicated. The machine is going to utilize an Ethernet router to establish an internal network that will be utilized to pass data from the signal conditioners to the CPU and the PLC. All modules in this network will be assigned a static IP address.

To begin the manufacturing process of this machine all current electrical components, wiring, and mounting devices will be removed. To insert the new touch screen the front of the machine will need to be cut out so a new mounting can be riveted onto the front. The current design utilizes a module mounting rack for the PLC, a similar style mounting will be manufactured to replace it. For the rest of the electrical components a din rail will be mounted in the rear of the enclosure to attach the components to. When all components are inserted, wiring will be run and landed for all power, logic, and communication needs. When all is assembled the final stages of testing and debugging can commence.

Procurement

In order to begin the procurement process, we needed to finalize one basic aspect of our design. We needed to figure out what power system we are going to run the various components of the bore gauge on. We decided that we want to run this system off of 24VDC/120VAC power. This freed us up to start doing research on individual components that we will need. It was decided that everyone in the group would come up with several options for an assigned component of the design. From our contact at Koyo Bearings, Robert Potts, we have learned that we will be provided with a CPU, eliminating it from the selection process. There are individual specifications that each option must meet as well as the overall voltage requirement. Each component will be evaluated by all team members and the team will select the best and second best design. These two designs will then be presented to Robert Potts and together with the team a decision will be made on the final design. Once the design is finalized with Mr. Potts, we will order the parts online at the best price possible. Time for delivery will be considered in the selection process. The team would like to have all essential parts of the design ordered by mid-November to ensure they arrive before spring semester starts so that it is possible to get started on assembly immediately.

Environmental and Safety Issues and Ethics

Environmental

The machine being updated does not contain any hazardous chemicals. So there will not be any environmental issue that deal with the containment of chemicals. The machine is designed with a low energy use, so there will less impact on the environment.

Safety

All work to be done on the machine will follow a strict lock out tag out (LOTO) procedure on all potential energy. We will obtain locks and tag out equipment so that each person working on the machine will have lock on the any potential energy. This will keep everyone safe during the manufacturing of this machine.

The machine has been design with a locking mechanism on both electrical housing. This way once the machine is completed and placed on the manufacturing floor at the Koyo plant there will no access to the electrical components by unauthorized personnel.

Ethics

The machine was designed after modeling the original machine. We are not using any of the original electrical components in the design nor are we doing any reverse engineering. Therefor there is no infringement on the previous design.

Conclusions

Koyo Bearing has requested an update to their automated high volume bearing bore gage. The mechanical aspects, pneumatic actuators and LVDTs, are currently performing at a level desired by Koyo Bearing. Therefore, we have decided to update the electrical components of the system. Four different component layouts were presented and a selection has been made. The chosen design includes a signal conditioner, PLC, CPU, touch monitor, and router. It is believed that these components will allow for an intuitive user interface, accurate measurements, and external communication to Koyo's plant. A design proposal, including bill of materials, has been sent to Koyo Bearings for approval. Once the design is approved, parts will be purchased through Koyo Bearings. The design will be implemented during the spring semester.

Future Work

Fall Semester

December

The plan for December is to get the acceptance back from Koyo Bearing on our design and budget. Once we get the acceptance back from Koyo we will order all the components needed for the design. We will also begin forming a schedule for the spring semester.

Spring Semester

January

The plan for January is to assemble all the components in machine, then check their operations. We will also be creating a test bed for the logic. This was we can ensure correct logic before implementing it on the actual product.

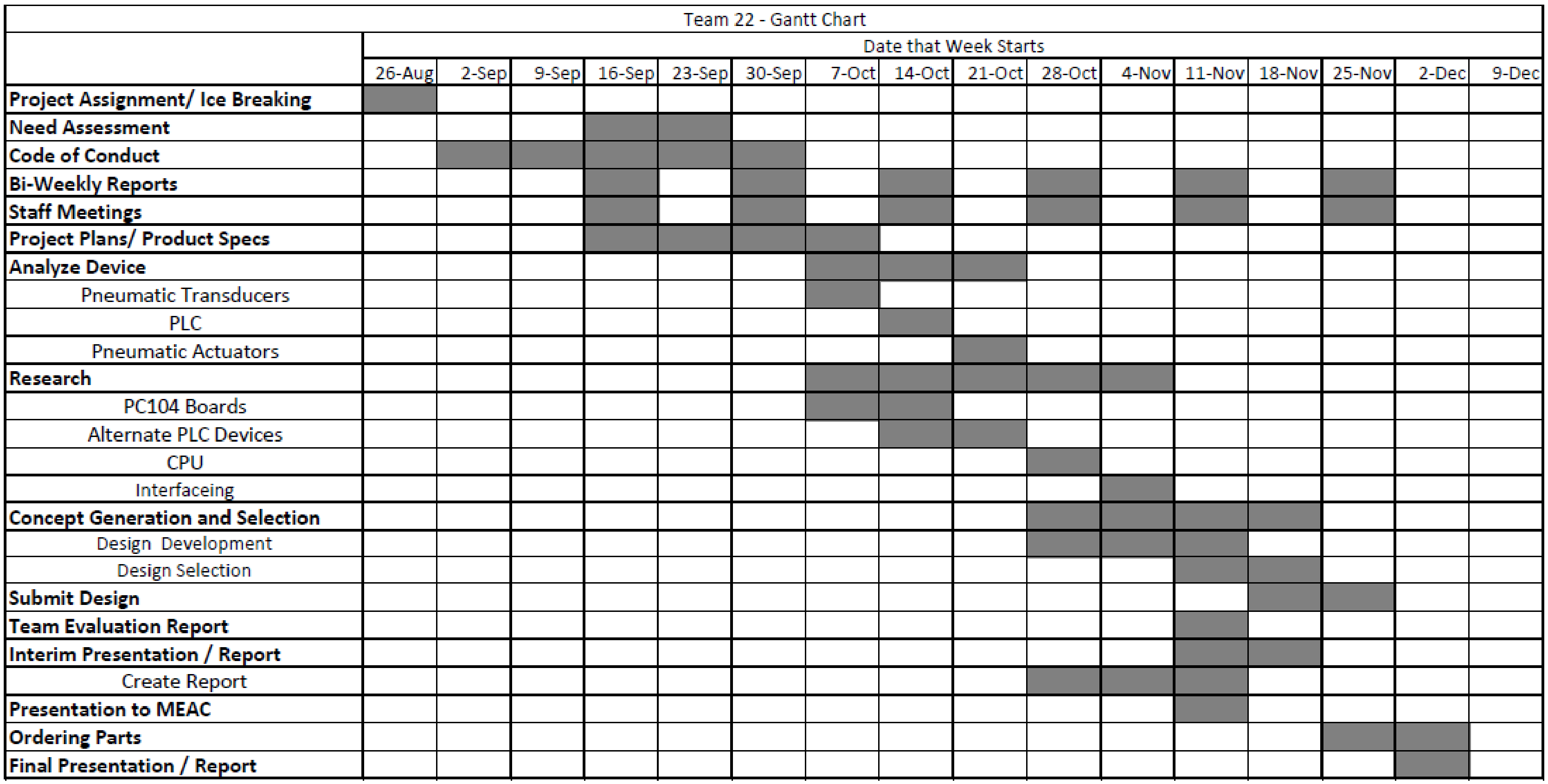
February and March

The plan for February and March is to write the program for PLC and CPU. Also configure the signal conditioner to work with LVDT in the air transducers. We will also be finalizing our design with testing and conditioning of the machine.

April

The plan for April is to finish debugging our system.

Gantt chart/ scheduling



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Appendix

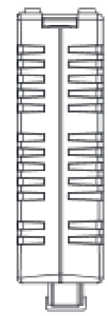
Components

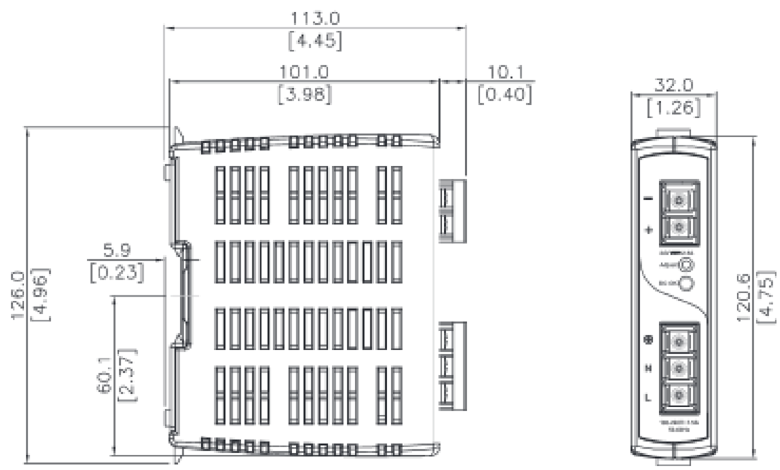
Power Supplies

PSB24-060-P (24V)

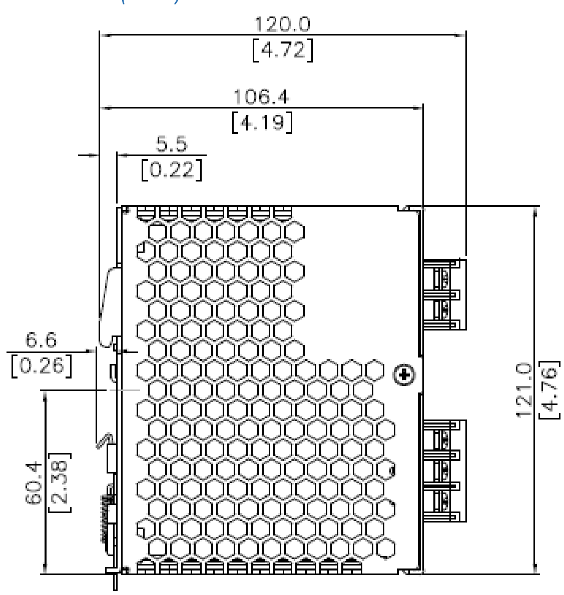
PSB24-060-P

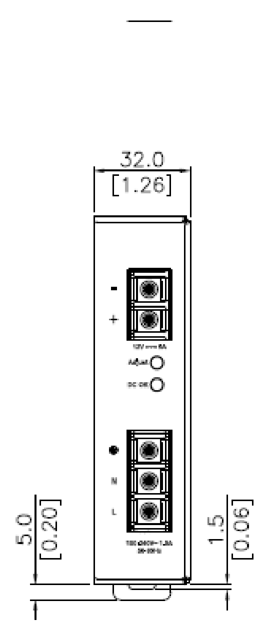
Wiring Connection			
Input		Output	
L	Line	+	Out +
N	Neutral	-	Out -
⏚	AC Ground		





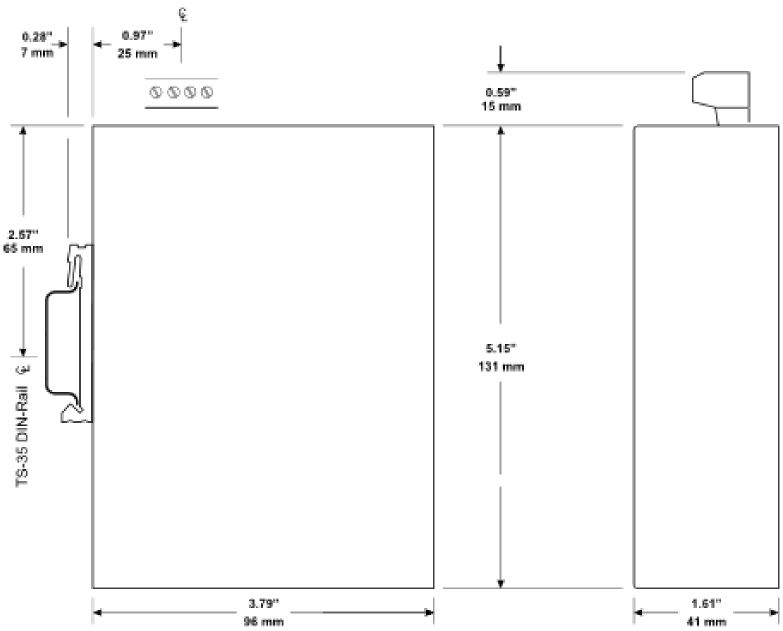
PSB12-060 (12V)





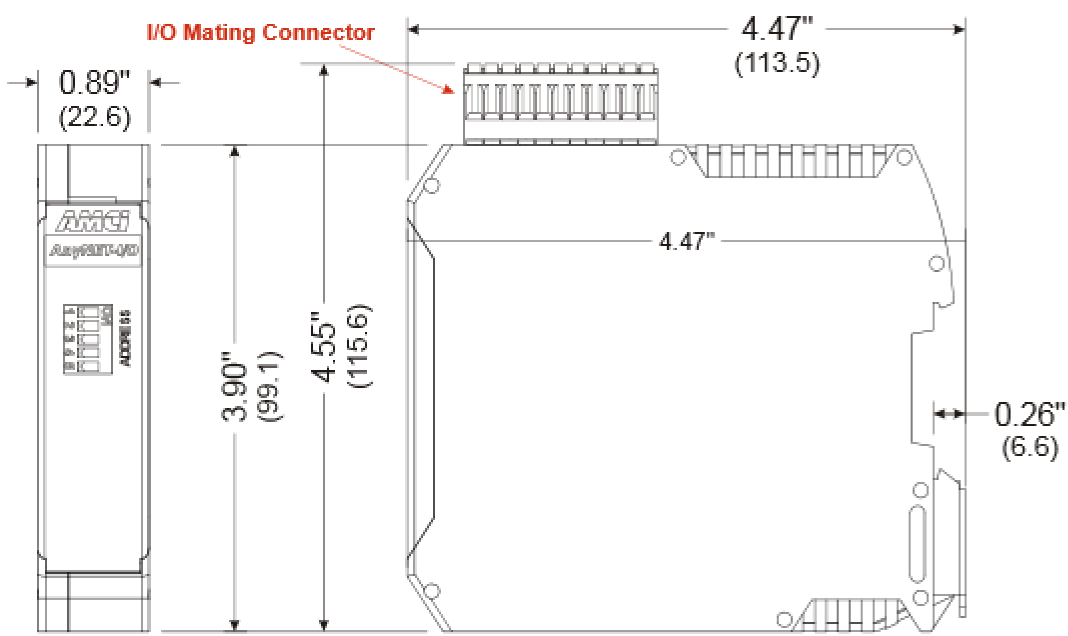
Router

CTR-Link EIPR-E



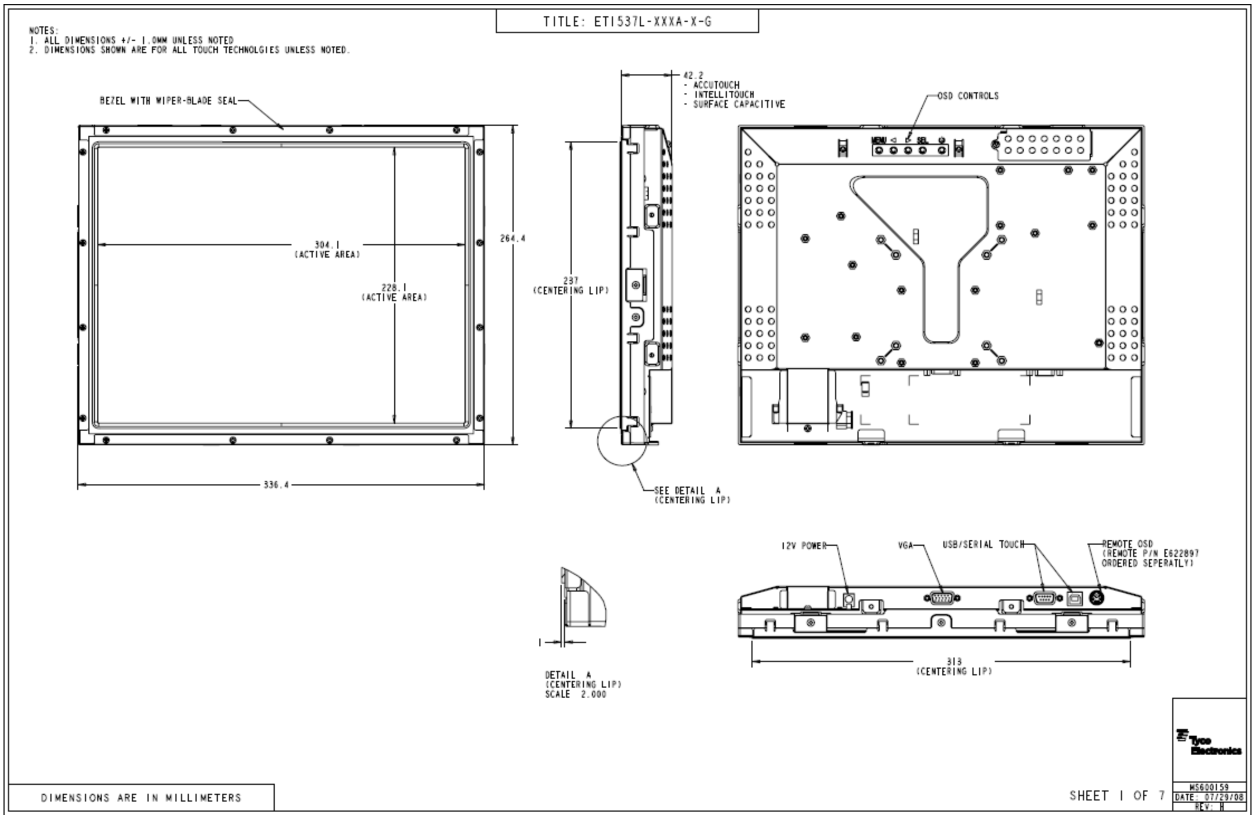
Signal Conditioner

AnyNET I/O ANR2 Network Compatible LVDT/RVDT Signal Conditioner



Monitor

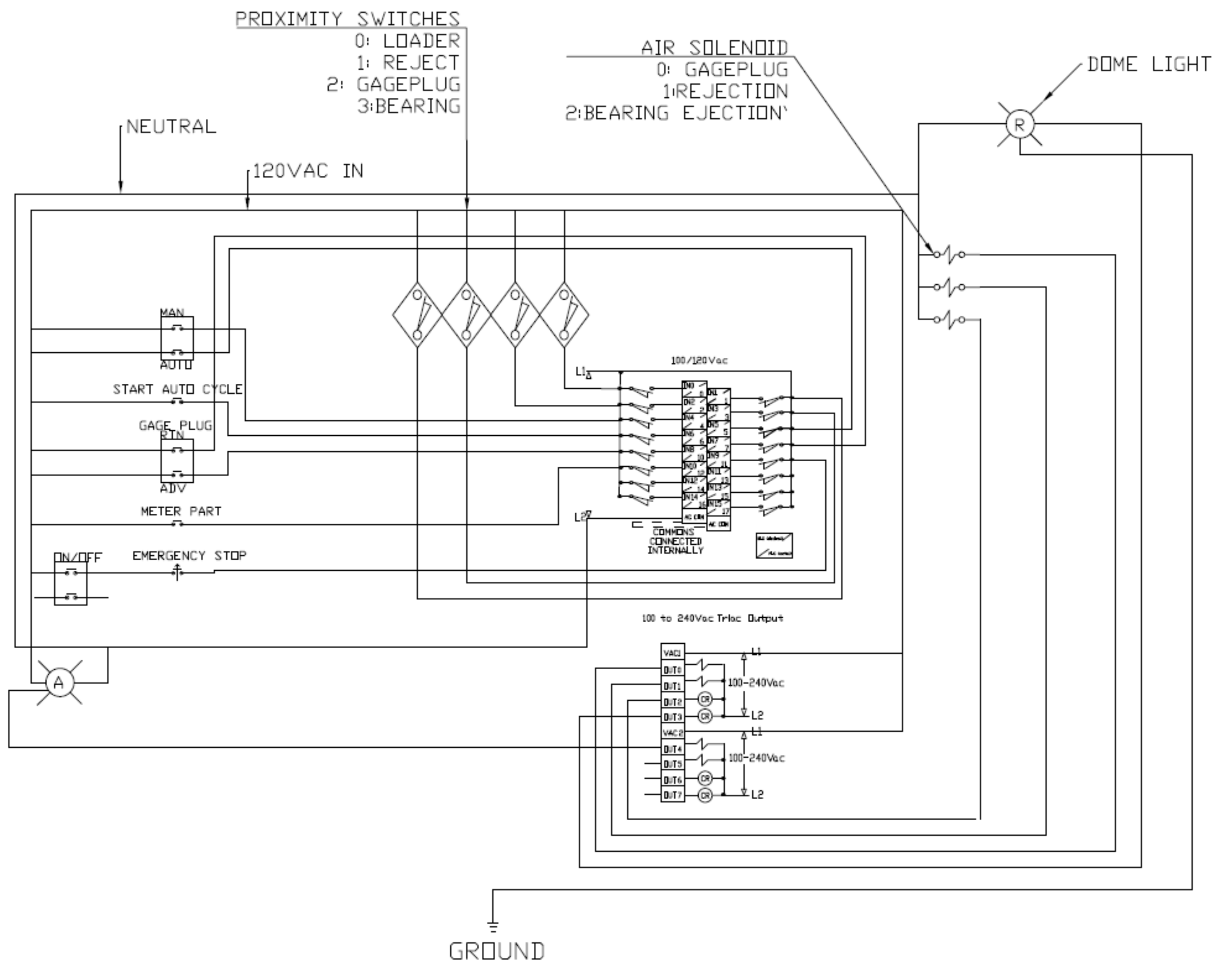
ELO 1537L



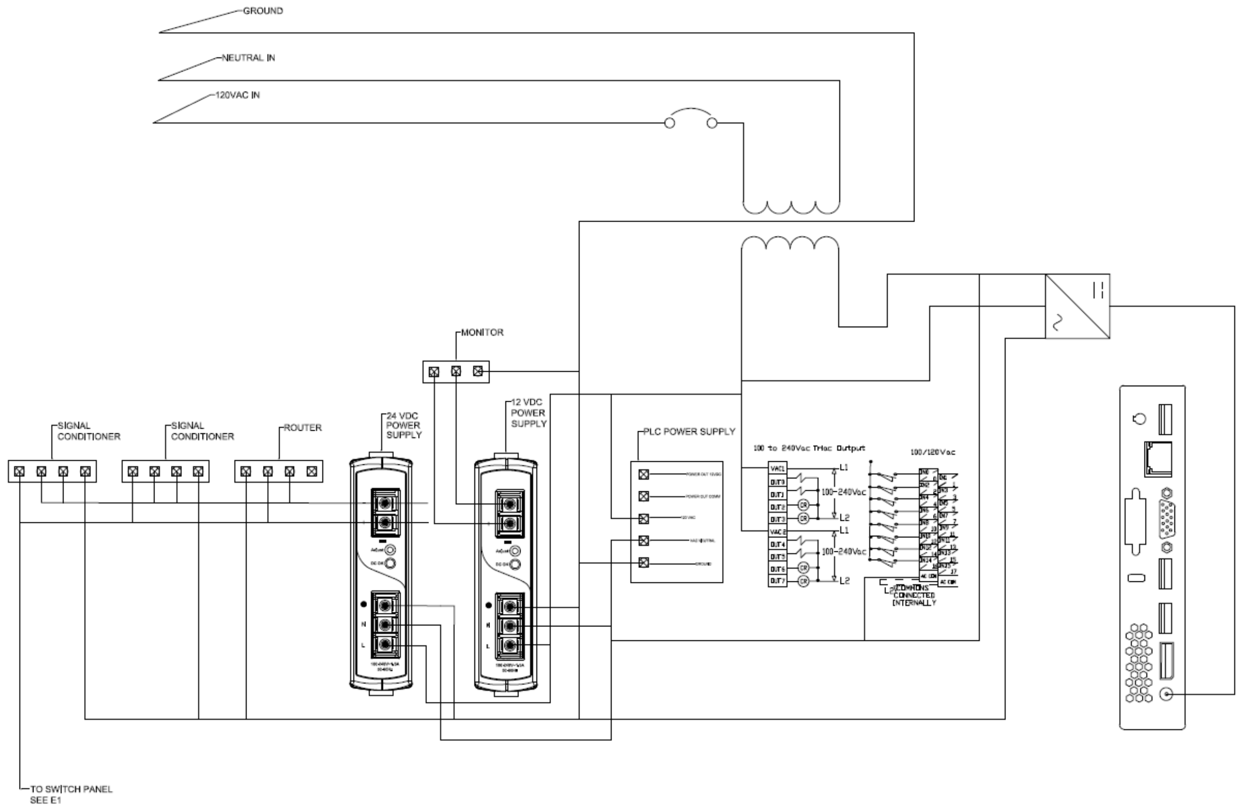
Layout

Electrical

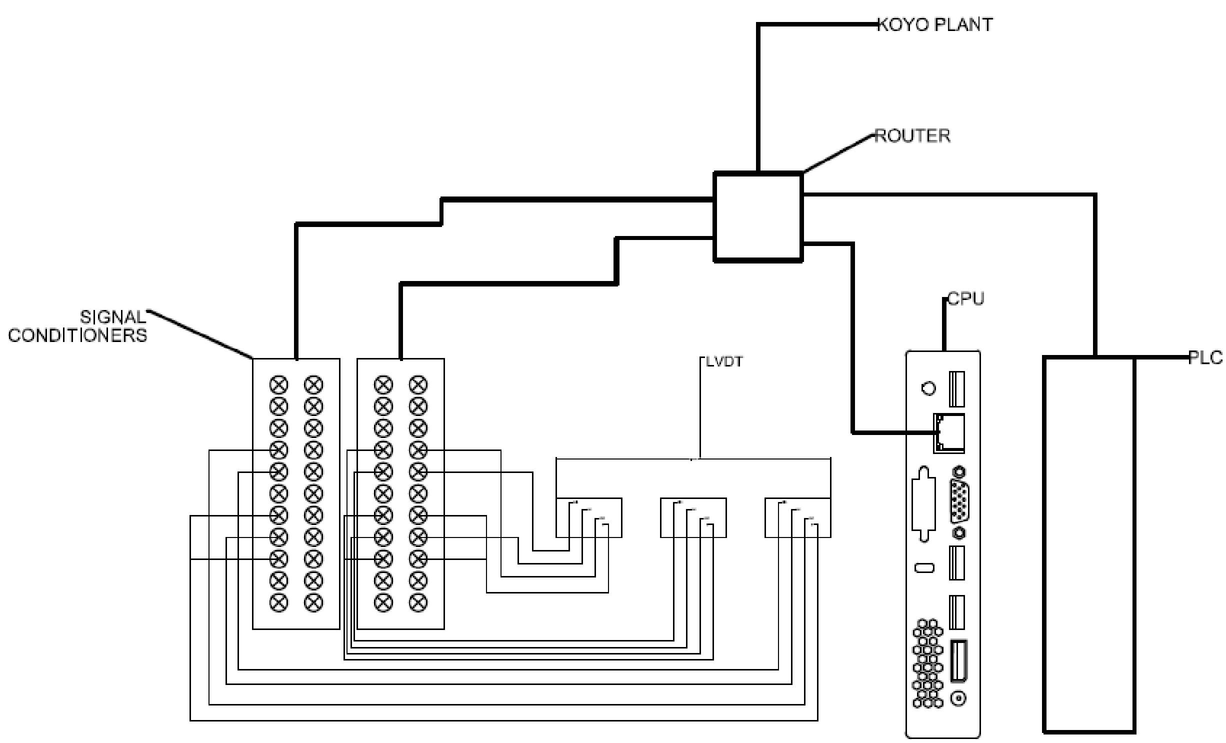
Logic



Power



Communication



Mechanical

Back Panel Components

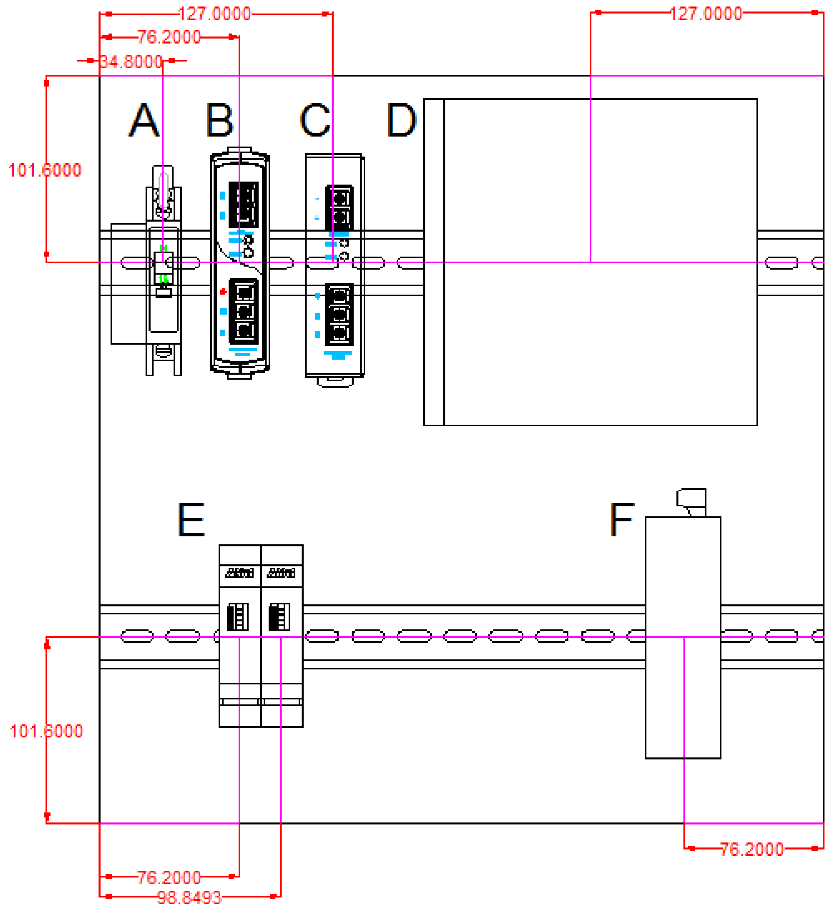


Table 5: Component Legend

	Part
A	10A circuit breaker
B	12VDC Power Supply
C	24VDC Power Supply
D	CPU
E	Signal Conditioner
F	Ethernet Router

Housing Diagram