Team 22 –Automated High volume Bearing Bore Gage

Design Concepts

Midterm Report

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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The objective of this project is to improve the out of date bearing bore gage system used by Koyo Bearings.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 are now researching interfacing options and have come up with a design implementing a signal conditioner from the LVDT to the exiting PLC and to a new CPU. The CPU will output bearing information to the new display. We will make a bill of materials for the project and get it approved by Koyo before ordering. In our research of the individual components of the design we have come to the conclusion that price may be an issue and we are working on a realistic budget.

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The objective of this project is to improve the out-of-date bearing bore gage system used by Koyo Bearings.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
- 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.
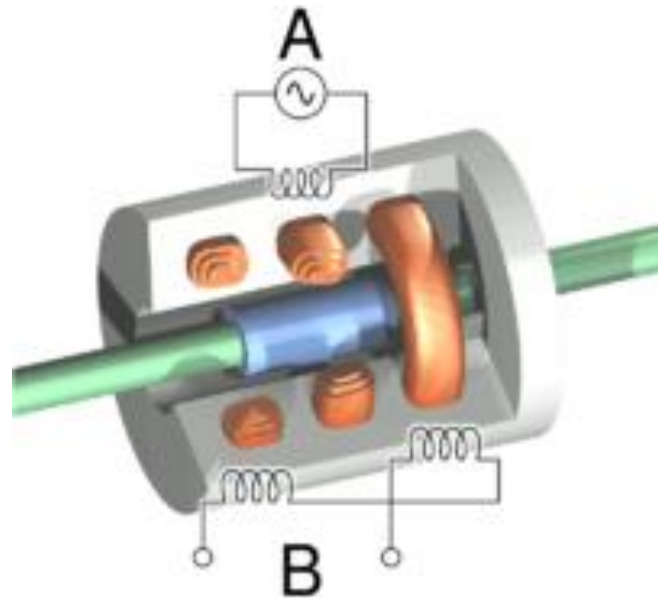

Figure 1: Schematic of an LVDT

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

Figure 2: Schematic of a pneumatic actuator

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.
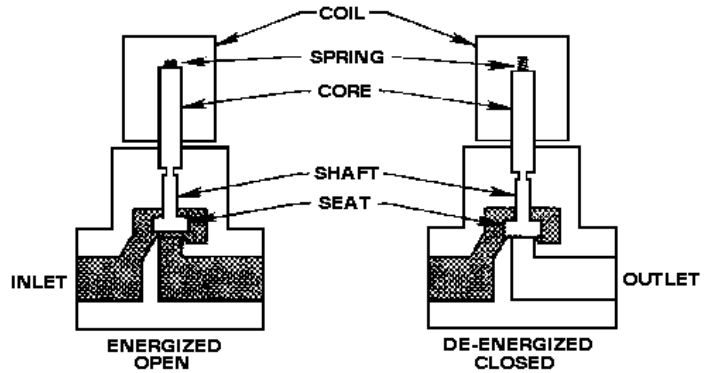
The final section of the device is electrical. In this section, the electrical signals from the LVDTs are conditioned and analyzed. The information contained in the signals must be transmitted to the PLC for a decision on tolerances. This must be then transmitted to the linear actuators in order to pass 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.
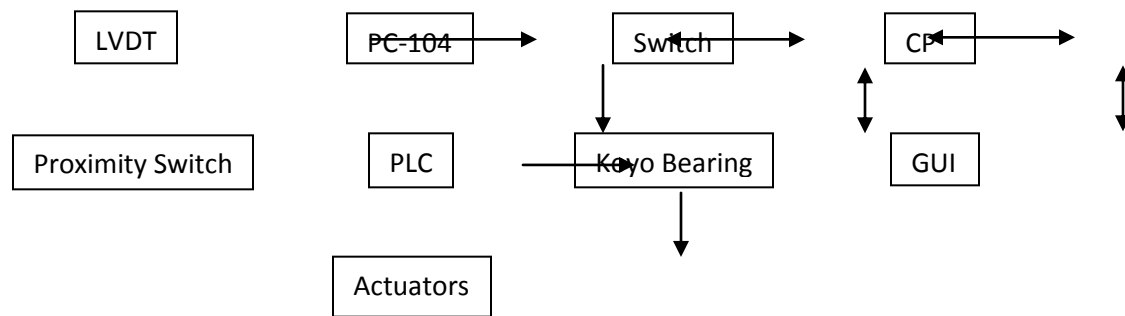
Figure 3: Communication Diagram of Concept 1

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.
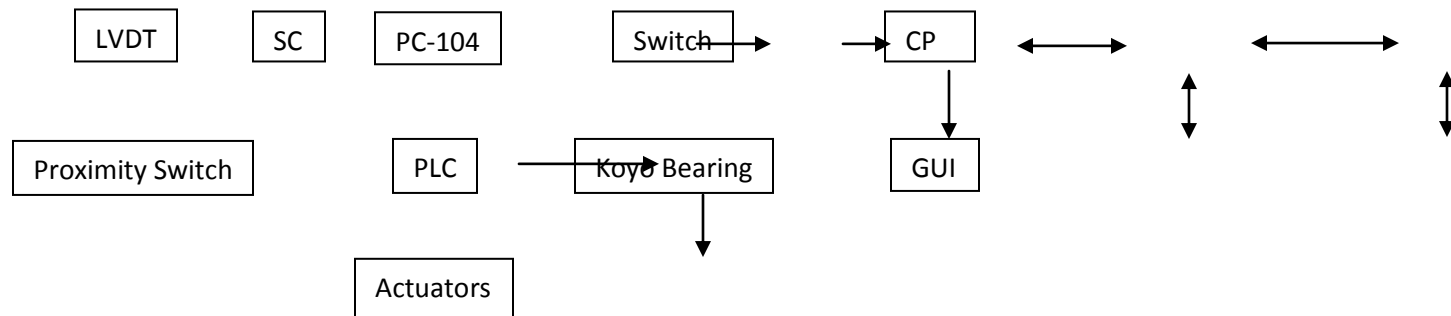
Figure 4: Communication Diagram of Concept 2

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.
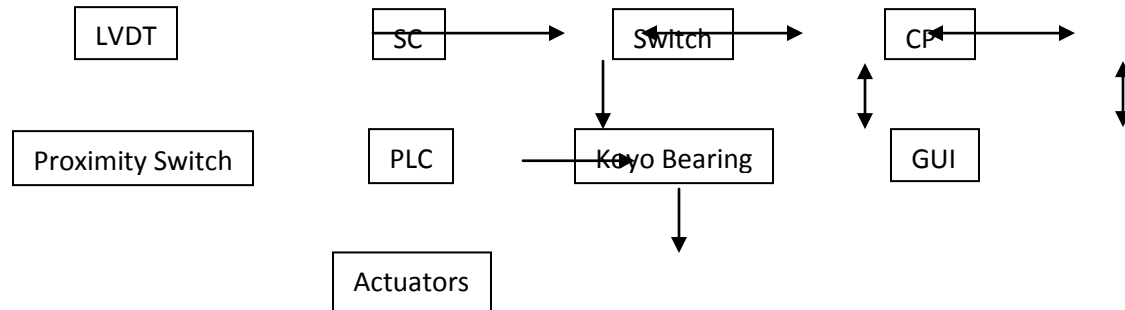
LVDT		SC	→	Switch	→	CPU	→

Proximity Switch		PLC		Koyo Bearing		GUI	

Actuators

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.

LVDT		SC	→	CPU	↔	GUI	↔

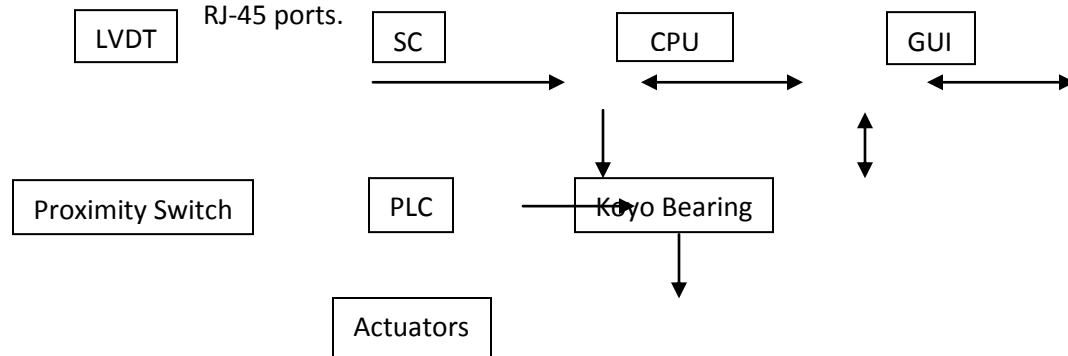| Proximity Switch		PLC		Koyo Bearing	

Actuators

Figure 6: Communication Diagram of Concept 4

Evaluation of Designs

Thus far, no decision has been made as to which concept will be implemented. A decision matrix will be created in early November to make this selection. It will contain crucial information to the design including, cost, power consumption, simplicity, and ease of repair.

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. If it fits within the allowable budget, then this display will be used. If it does not fit within budget, then a smaller version will be selected.

Programming Needs and Control

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 will only need to be edited to accept the new signal. There will not be a need to reprogram the PLC to control the pneumatic linear actuators.

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.

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.

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 will be made in early November.

Several options for electrical components have been found. All run on 24VDC and are DIN rail mountable to increase the simplicity of the system as well as the installation. So far, no decision has been made on these parts, but all are capable of performing the necessary tasks.

Once our design, including electrical components has been finalized, we will create a bill of materials for Koyo Bearing. Once they have given approval we will move into the next phase of the design process, ordering parts and creating the spring schedule.

Future Work

Fall Semester
October

The plan for October is to finish our research on the equipment on the needed for machine design.

November
The plan for November is to finalize the design for the machine. We will make the electrical schematic for all components of the machine. We will also make a billing of material and a budget for the machine. We will then send the schematics, bill of material, and the budget for the machine to Koyo Bearing.

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.

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

Team 22 - Gantt Chart																
	Date that Week Starts															
	26-Aug	2-Sep	9-Sep	16-Sep	23-Sep	30-Sep	7-Oct	14-Oct	21-Oct	28-Oct	4-Nov	11-Nov	18-Nov	25-Nov	2-Dec	9-Dec
Project Assignment/ Ice Breaking	▓															
Need Assessment				▓	▓											
Code of Conduct		▓	▓	▓	▓	▓										
Bi-Weekly Reports				▓		▓		▓		▓		▓		▓		
Staff Meetings				▓		▓		▓		▓		▓		▓		
Project Plans/ Product Specs				▓	▓	▓										
Analyze Device							▓	▓	▓							
Pneumatic Transducers							▓									
PLC								▓								
Pneumatic Actuators									▓							
Research							▓	▓	▓	▓						
PC104 Boards							▓	▓								
Alternate PLC Devices								▓	▓							
CPU										▓						
Interfaceing											▓					
Concept Generation and Selection										▓	▓	▓	▓			
Design Development										▓	▓					
Design Selection												▓	▓			
Submit Design													▓	▓		
Team Evaluation Report												▓				
Interim Presentation / Report												▓	▓			
Create Report										▓		▓				
Presentation to MEAC												▓				
Ordering Parts														▓	▓	
Final Presentation / Report															▓	

References

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http://www.n-tron.com/products_detail.php?product=32&series=14

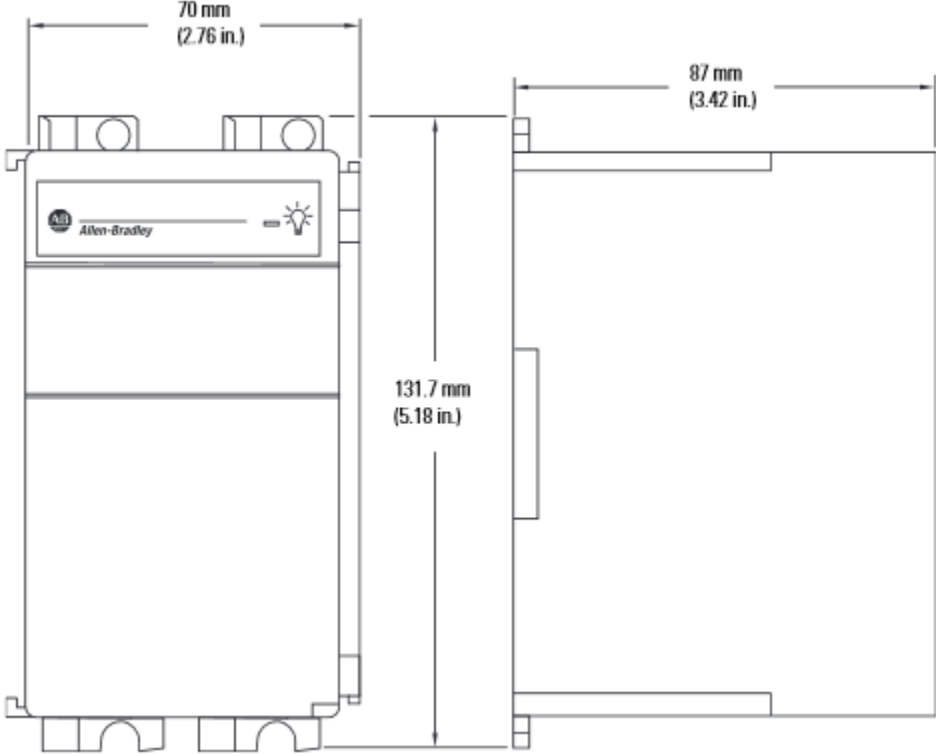http://www.startech.com/Networking-IO/Switches/5-Port-Unmanaged-Industrial-Ethernet-Switch-DIN-Rail-Mountable~IES5100

http://www.koyousa.com/
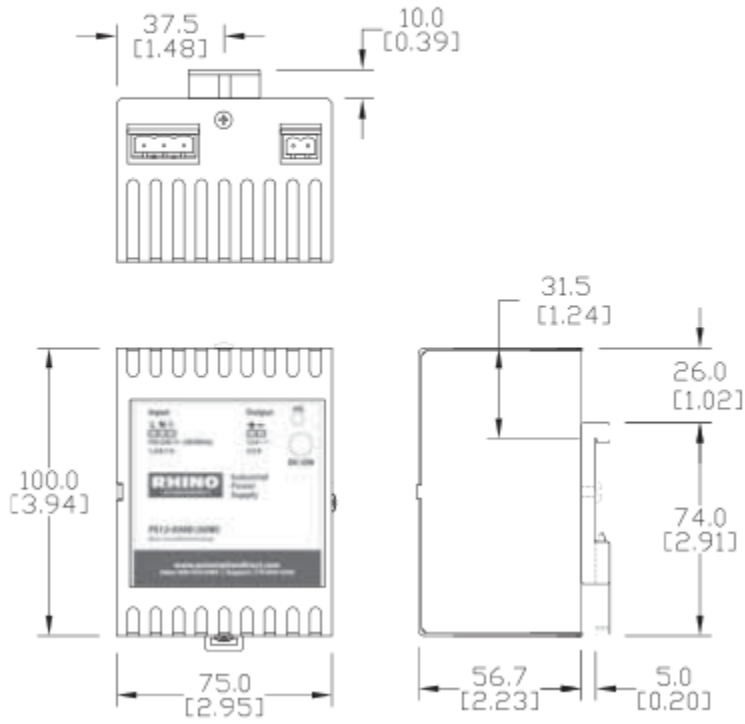
Appendix

CAD Files

Power Supplies

1769-PA4

PS12-050D, PS24-050D
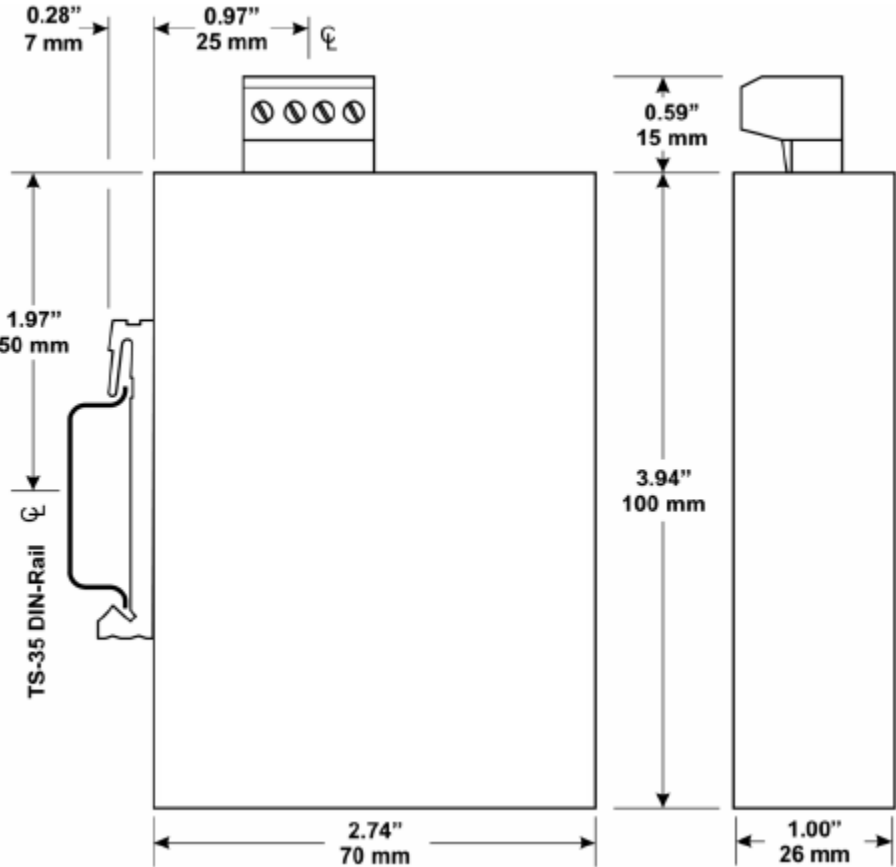
PSB24-060-P

Wiring Connection			
Input		**Output**	
L	Line	+	Out +
N	Neutral	–	Out –
⏚	AC Ground		
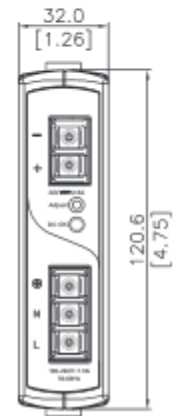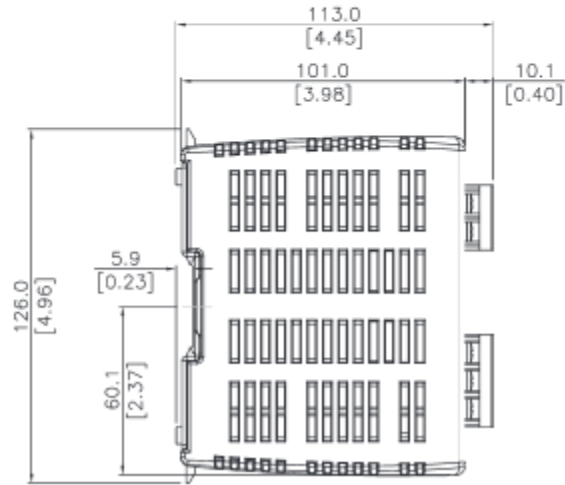
Ethernet Switches

EISK5-GT

IES5100

1.00"
[25.40mm]

3.85"
[97.71mm]

3.61"
[91.65mm]

3.85"
[97.77mm]

1.20"
[30.42mm]

4.37"
[110.97mm]

4.00"
[101.60mm]

N-TRON

LNK
ACT
1
SPD
1000

LNK
ACT
2
SPD
1000

LNK
ACT
3
SPD
1000

LNK
ACT
4
SPD
1000

LNK
ACT
5
SPD
1000

1005TX
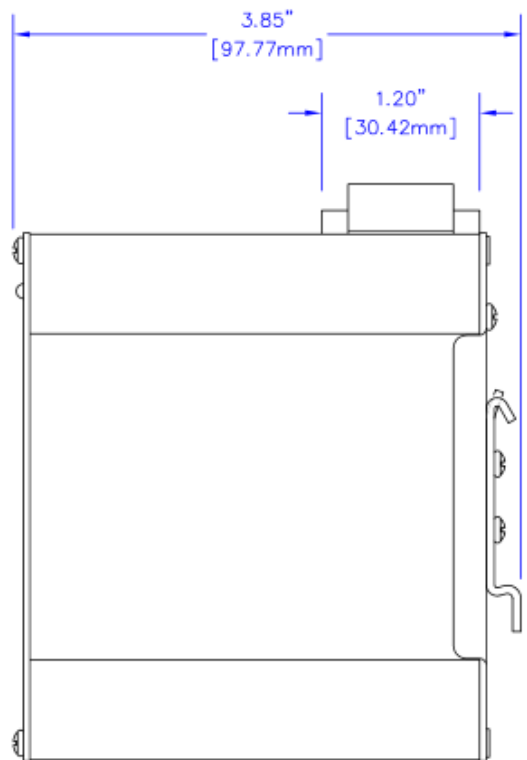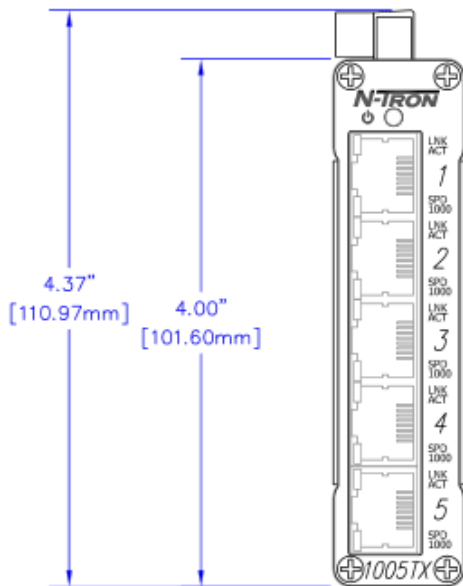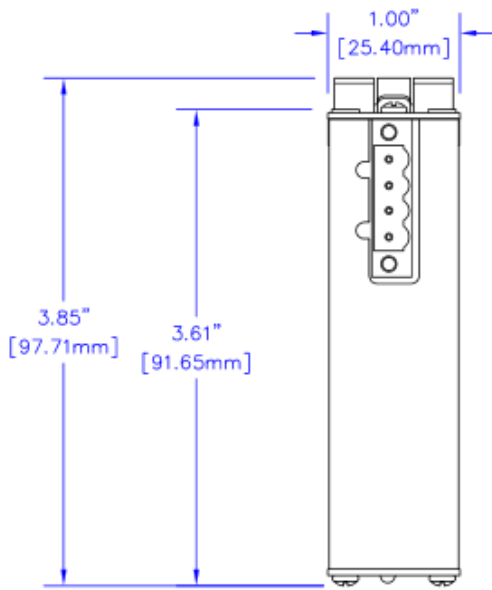
Signal Conditioner
AnyNET I/O ANR2 Network Compatible LVDT/RVDT Signal Conditioner