CONVEYOR AUTOMATION AND CONTROL SYSTEM

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We hereby declare that we are the sole authors of this report.

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Abstract

With the rapidly growing cannabis industry – especially in cannabis farms, innovation has been geared towards automation and process efficiency. Automation can be best applied once data is analyzed. One critical data in the greenhouses is the product volume flow rate. This report provides an overview of the problem statement based on the RFP released by Keirton, a description of the design approach and implementation, and a discussion of the results obtained. The project involves the design and prototype of a volume flow rate measurement control system that allows manual or automatic motor speed control. The volume flow rate measurement device is achieved using a custom designed level measurement device in conjunction with a PLC. A MSP430 microcontroller is used as part of the sensor to output a cross-sectional area measurement to the PLC where it is used with speed data from the VFD to calculate the volume flow rate. An HMI (human-machine interface) displays the current volume flow rate through the sensor and allows the user to choose one of two available modes. Automatic mode requires a user input volume flow rate setpoint and adjusts the motor speed accordingly to achieve the setpoint. Manual mode only displays the volume flow rate reading and allows users to control conveyor speed directly. The project cost came to $4,500, and termination date was May 10, 2019.

Acknowledgments

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The team would also like to thank our BCIT project supervisor, Adam Marciniak and Johan Fourie, whose weekly meetings and professional advice kept the team on track and steered the team to completion.

We would also like to thank Kathy Manson and Hassan Saberi from the BCIT electrical engineering department for electrical design and Siemens software support. Kathy helped the team with the wiring of the control panel where the team had little background in. Hassan provided guidance on where to find information to implement the Siemens VFD drive into TIA Portal. Kathy and Hassan provided a significant contribution in helping the team cross major road blocks early in the project.

We would also like to extend our gratitude to E.B. Horsman and Son. Their company representatives provided support for equipment troubleshooting and commissioning.

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1 Introduction

1.1 Project statement and objectives

This project is in response to an RFP (Request for Proposal) released by Keirton for the project Conveyor Automation and Control, in September 2018 (See Appendix Section A). The main objective is to measure the volume flow rate on the conveyor used in their Twister Trimmer products. Keirton is a specialty crop trimming machine designer and manufacturer. Their product line, Twister Trimmer, is composed of a trimming machine, conveyor, vacuum suction and other accessory devices, most commonly used in the cannabis industry. An example, shown in Figure 1-1 below, features three trimmers in tandem with an infeed and outfeed conveyor. The volume flow rate measurement design will be applied to the infeed conveyor (right hand side).

Figure 1-1: Twister Trimmer with Infeed and Outfeed Conveyor [1]

Various parameters are adjusted such as material feed rate into the conveyor and trimmer rotational speed to achieve optimal trim quality. One parameter that is especially useful to allow customers to monitor their trimming assembly is the product infeed volume flow rate. The project revolves around the design of a control system that measures and displays the volume flow rate going through the Twister conveyor and controls the conveyor speed to obtain a set volume feed rate into the Twister trimming machine. The design should also include a human-machine interface that allows users to input a volume flow rate set point and or allow users to control the conveyor speed manually to achieve the desired volume flow rate setpoint. By giving users access and control over their product flow data and machine parameters, they are able to find the best combination of settings to optimize their process.

1.2 Scope and Deliverables

The sponsor company and team members have identified the following to be the significant requirements of the project: (1) read and display volume flow rate of product on the conveyor, (2) use company specified electrical components, and (3) minimal modifications to the conveyor assembly. These objectives are used as a baseline in the development of the project schedule and corresponding project milestones. These requirements are discussed in more detail in Chapter 2.3, critical requirements.

The deliverables are:

- Prepared presentation with technical report.
- Fully integrated system prototyped using the given test bench.
- Complete design documentation including:
    - BOM for any off-the-shelf components
    - Manufacturing drawings of all custom parts
    - PLC program

The project requires complete documentation of electrical and mechanical design for the volume flow rate sensor. This includes a comprehensive bill of materials for all off-the-shelf electrical and mechanical components. All custom designs should also be accompanied by relevant technical drawings.

The volume flow rate controls should allow for users to input their own volume flow rate setpoint but also allow for manual speed control. All programs written should also be documented properly. Instruction manuals should also be provided for all manual controls involved in the project.

Lastly, the design should be tested using the given test bench (T2 conveyor as shown in Figure 2-1). The sensor mount should require minimal modification to the current conveyor assembly. The control panel used to control conveyor speed should use company supplied electrical components to allow for easy integration.

2 Detailed description of current status

2.1 Twister Conveyor

This project will use a T2 conveyor to build on (figure 2-1). A common customer set up includes a conveyor that feeds into a trimmer. The most common data collected and analyzed is the output of the conveyor-trimmer assembly. This may be measured based on the volume of trimmed material per unit time or weight of trimmed material per unit time. This output is affected by a number of parameters such as trimmer RPM, conveyor speed rate, and plant moisture content to name a few. For smaller set-ups with smaller machines, the effect of these parameters is not very critical on the overall output data. However, when bigger machines are used and a much greater volume of material is involved, the impact of minute changes in these parameters increase significantly. Knowing the input rate becomes just as important as the output rate to best monitor the efficiency of the machine and allow customers to calibrate the machine parameters to maximize potential efficiency.

Figure 2-1: Twister T2 Trimmer & Conveyor [1]

As machines get bigger and more complex, so do the electrical components. Independent control units are designed for the conveyor, machine, and accessories. Integration of these individual components becomes more difficult – not only with each other but also from supplier to customer. This is where the project need is best shown – a measurement device to keep track of input rate in terms of volume feed rate and allow for easy integration with the rest of the set-up components.

2.2 Set-up Parameters

There are numerous parameters involved in achieving the best efficiency when using a conveyor-trimmer set up. Since the scope of this project is limited only to the conveyor, only parameters involved in obtaining the volume flow rate will be discussed.

One important parameter is the linear speed of the conveyor. The project is constrained to the rated speed of the motor the conveyor uses. The design of the control panel to allow for variable speed control is dependent on the motor rating. All components of the control panel such as PLC, VFD, and HMI should also meet project requirements – use of Siemens components. By matching to Keirton's electronics, the design can be easily integrated to use with other conveyor assemblies such as T4 and T-Zero machines, and with top-level control panels used for entire machine-conveyer set-ups.

The cross-sectional area of the conveyor is also one parameter that needs to be an input to the program since it varies from one machine to another. This can be easily integrated in the calibration function. Calibration of the sensor is further discussed in the future work section of the report.

Since material being fed on the conveyor is not always level, it is a parameter that needs to be manipulated or considered during the design to accurately measure volume flow rate. The nature of the product can also cause variance in density that can lead to faulty measurements when they loosen up from being clumped up. These difficulties are discussed in detail in later sections as well as how they are addressed during the design process.

2.3 Critical Requirements

Critical requirements are used to guide the design process, used as baseline or constraints. These requirements are subdivided to three main categories – electrical, mechanical, and software.

The following is a list of electrical requirements of the project:

- Use of Keirton specified components: Siemens products
- Use current conveyor motor
- Allow user input

The company requires that the electrical components used in the design of the control panel be Siemens products. This allows the control system to be easily integrated to other Twister machines. The control panel should also be designed to power the motor already installed in the conveyor assembly. This allows the variable speed design to be implemented to other T2 conveyors. The project also requires that the design allow user input. This is met using an HMI panel, further discussed in the electrical design section.

The software requirements are closely related to the electrical requirements. The project requires that the control system use the same software/programming language as Keirton to allow for integration to other products. This is already met by using the same electrical components. Siemens provides a software that allows programming and commissioning of all components in one platform.

Lastly, the project requires that all mechanical design be developed around the current conveyor assembly. This means that all mounting mechanisms needed for measurement devices require minimal modifications to the conveyor assembly. Such modifications should be easily mountable or installed using hand tools. This requirement allows the sensor to be easily mounted to conveyors already in service.

2.4 Hypothesis

The project aims to specify an off-the-shelf sensor that can be used to measure volume flow rate or a parameter that the PLC can use to measure volume flow rate. The team aims to design a mount for the sensor on the machine and achieve communication between the sensor and the PLC.

3 Theoretical background

3.1 Volume flow rate measurement devices

Various volume measurement devices and set-ups are already being used in other industries. For bulk material such as wood chips, laser scanners are used to measure cross-sectional area of material on the conveyor. It is then combined with the known conveyor speed to obtain the volume flow rate. The same method is used in the mining industry, seen in figure 3-1 [1].

Figure 3-1: A depiction of a cross sectional area measurement device. [2]

Most level measurement systems come with their own independent control system. This conflicts with one of the requirements that the sensor be able to communicate with the control panel design. The sensor has to be bought separately from its control system.

Most volume flow rate measurement devices are also only supplied to large scale applications. These devices are too expensive for small scale applications like this project. This project only aims to provide a proof of concept using a small-scale test bench, which can then be later improved and applied to larger scale machines.

Since the quality of product is affected by the amount of mechanical manipulation it goes through during processing, it is also critical that the sensor ideally does not contact the product or inflict extensive mechanical manipulation.

Based on these findings, the project uses a level sensor, assuming that material is coming through at a level height, and uses this height reading to calculate volume flow rate.

3.2 Sensor design

Figure 3-2: LMI Laser Scanner [3]

One proposed design is a laser scanner. Laser scanners can measure the cross-sectional area of material that is sitting atop of a conveyor. The sensor sizes are able to cover the area required to measure flow on the conveyor, although the resolution of the scanners is much higher than required. Laser scanners are usually used to scan parts on conveyor during quality control. Other uses are for 3D scanning of complex parts.

Figure 3-3: Micro Wave Solid Flow Measurement Devise [4]

The microwave sensor utilizes microwave technology to measure the number of solid particles that pass through it. It is capable of measuring the volume flow rate of material that passes through it [2]. It is mostly used for materials, mostly dust and granules, going through a closed metallic container.

For this project, if budget allows, the laser scanner can be used to test the concept and write the PLC program needed to control conveyor speed.

3.3 Variable motor speed design

Figure 3-4: Siemens Variable Frequency Drive (VFD)

The most widely used device for variable motor speed is the VFD (Variable Frequency Devices). VFD devices vary the frequency and voltage that is supplied to the motor to control the motor. The VFD can be powered by single phase power and supply the motor three phase power. The VFD uses a series of diodes that open and close to create the three frequency phases [3].

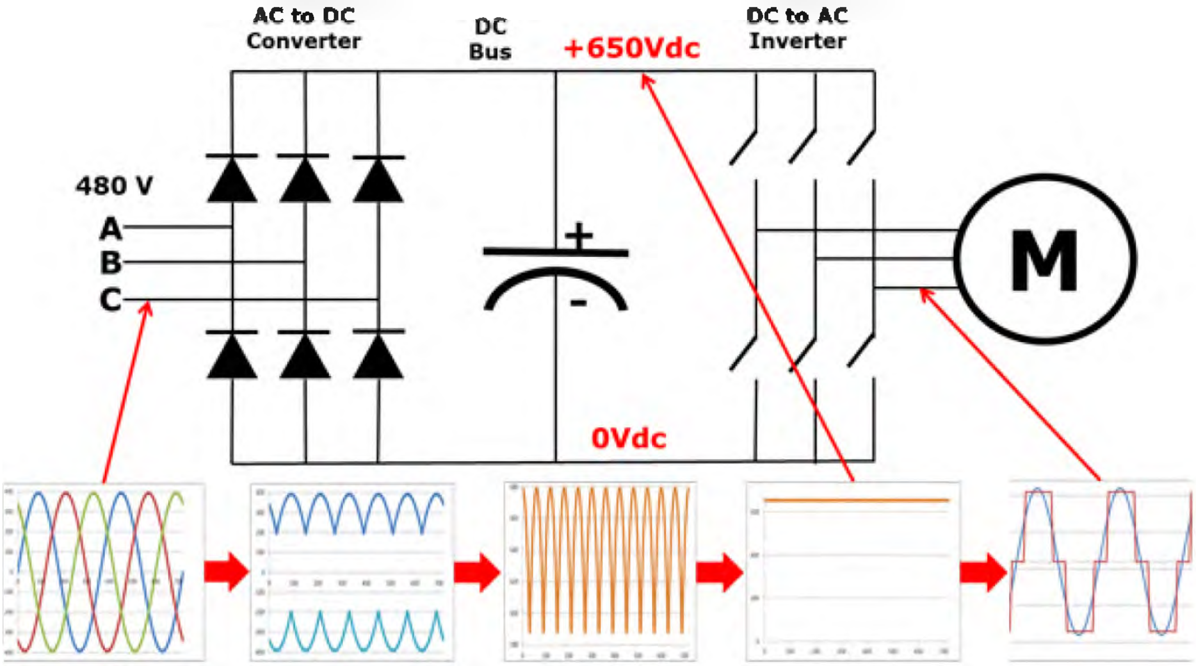

Figure 3-5: Functional Diagram of a Variable Frequency Drive (VFD) [5]

4 Description of the Project Activity and Equipment

The design of the project is split into three main categories – electrical, mechanical, and software. Each will be discussed in detail in the following sections. Figure 4-1 below shows a top-level view of the major components under each category.

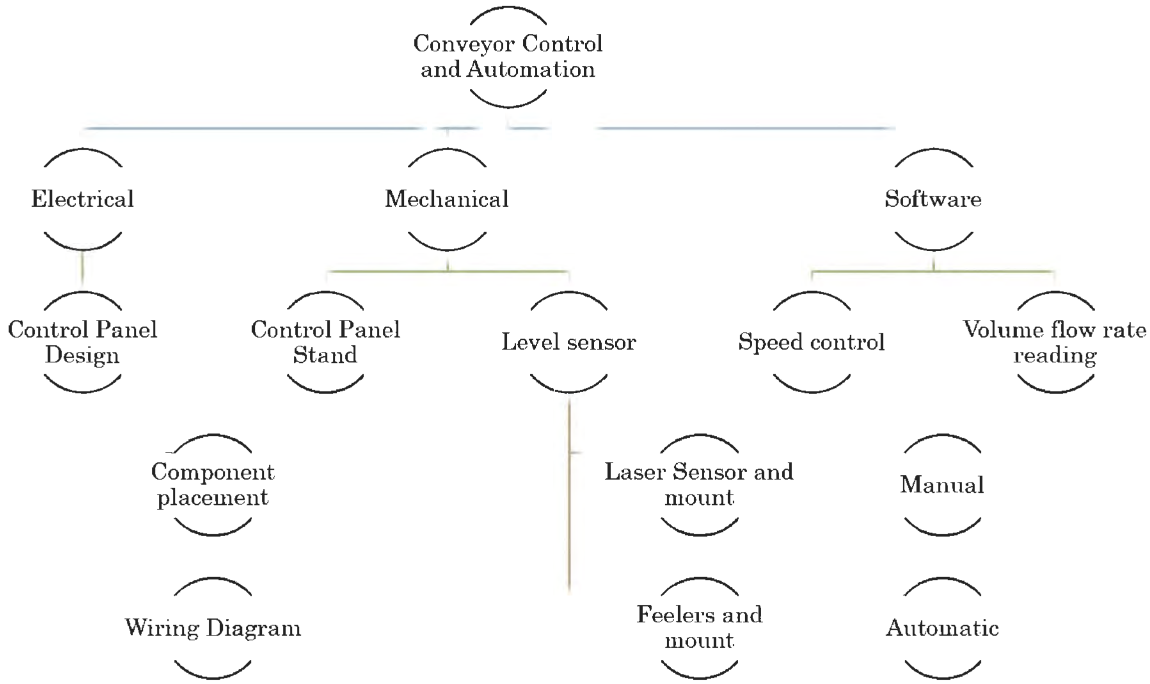

Figure 4-1: Design Process Decomposition

4.1 Electrical

4.1.1 Power Wiring

Figure 4-2: Conveyor 3-Phase Induction Motor

As required, the electrical control panel was designed to provide power to the motor of the conveyor assembly and the Siemens electronics, while allowing for variable speed control and human-machine interface. The motor, Figure 4-2, requires 3-phase 240VAC. The electrical block diagram shown in Figure 4-3, shows the components that compromises the control panel. A detailed wiring schematic can be found in Figure D.1: Circuit diagram.

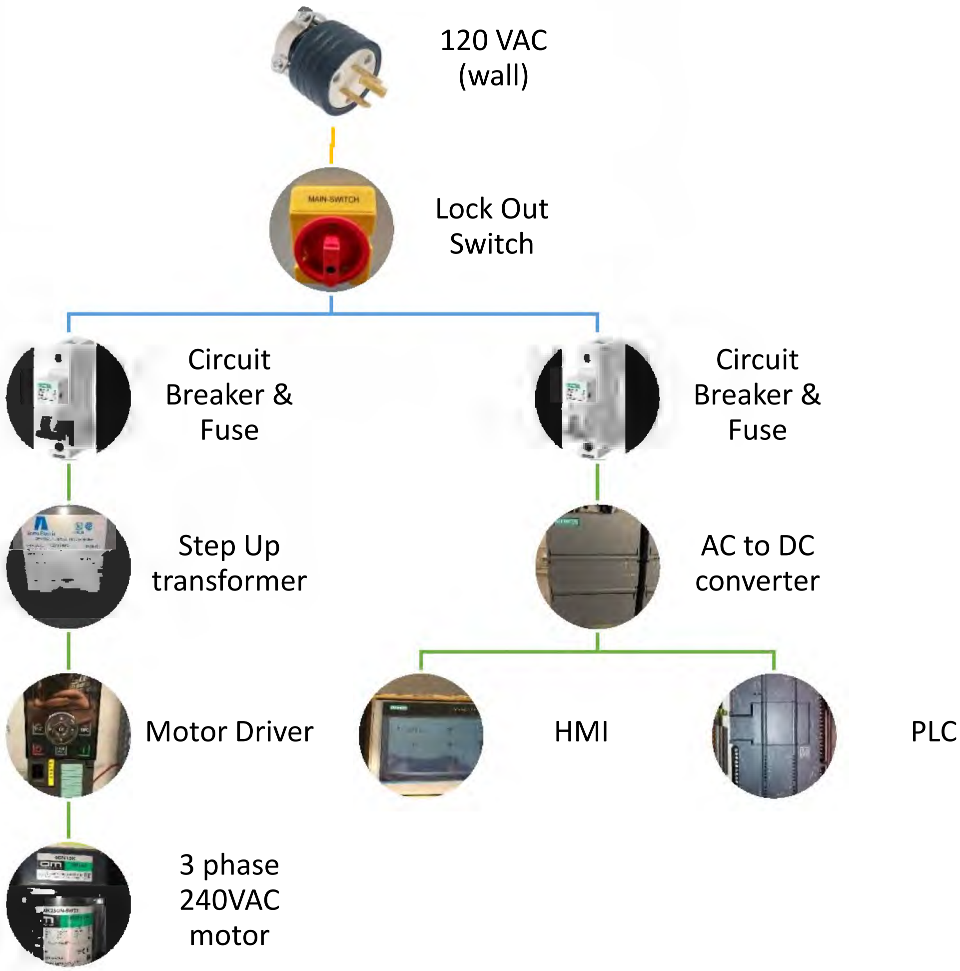

Figure 4-3: Electrical Block Diagram

Power can be supplied from any 120VAC North American wall plug. This allows the prototype to be tested at any facility without requiring a special power supply. The 120VAC immediately goes to a lockout switch and e-stop button for safety precautions. The power is then split into two circuit breakers. One circuit breaker is for the AC circuit and the other circuit breaker leads to the DC circuit. Each circuit breaker has a fuse connected in series for an additional layer of protection.

The AC circuit, coming from the circuit breaker, goes to a step-up transformer, bringing the voltage up to 240VAC from 120VAC. This single-phase 240VAC is then supplied to the motor driver/VFD. The VFD outputs 3-phase 240VAC that is used to power the motor and control the motor speed.

An AC to DC converter follows the second circuit breaker. It then supplies 24VDC to the PLC and the HMI. The PLC is used to power up and receive signals from the manual push buttons and the level sensor. Signal routing is discussed in the next section. The HMI, PLC, and VFD are all connected through an ethernet cable for inter-component communication.

4.1.2 Signal Wiring

The e-stop button was placed after the lock out switch and before the power lines diverge into the two circuit breakers. The location ensures that the e-stop button will cut power to both the external mechanical components and the internal electrical components to protect against both mechanical failure and electrical fires.

The three physical buttons on the control panel (start, mode select, stop) are wired as switches between the PLC 24VDC output and the input terminals. Detection of the button signals are done by checking to see if 24VDC is received by the input terminals.

The mechanical sensor is connected to the PLC through 10 wires. Two power lines and 8 signal wires to transmit the cross-sectional area measurement data through a relay. Using a relay allows for the sensor circuit and PLC circuit to be electrically decoupled. This eliminates the risk of supplying too much current to the PLC input terminals as with relays, the current feeding into the input terminals is the same current being output by the PLC.

4.2 Mechanical: Sensor Mount

Figure 4-4: Sensor Mount on Conveyor

The sensor mount shown in Figure 4-5, utilizes components already in the conveyor assembly. Two bent sheet metal brackets are the only new components added. This meets the requirement that any modifications to the assembly be minimal. The procedure of adding the sensor mount and the sensor itself requires the addition of six sets of bolts and nuts and tightening them. It can be easily mounted to conveyors already in service.

Figure 4-5: Sensor Mount and Leg Assembly

4.3 Electromechanical: Level Sensor

Due to the budget and time constraints of the project, using the laser scanner as sensor was not feasible. A level sensor was designed and built to measure the level of material on the conveyor.

The level sensor design uses a paddle lever connected to a potentiometer. As material goes through the conveyor and pushes the paddle up and down, the voltage reading through the potentiometer is read by a microcontroller. The program logic is discussed in Microcontroller C program. The height level measurement is converted to a cross-sectional area measurement using the geometry of the conveyor cross section in the microcontroller. The microcontroller then outputs a signal to relays which is read by the PLC. The PLC reads the output signal from the relays and uses the data in junction with the VFD speed data to obtain a volume flow rate measurement.

4.4 Software: PLC and Microcontroller

4.4.1 PLC Ladder Logic

Screencaps of the PLC ladder logic described is shown in Appendix section H.2 PLC Ladder Logic Code.

The main PLC ladder logic block is used to control the startup circuit, turn the VFD on/off, create setpoint limits, and call other function blocks. Other function blocks include: the logic for the toggle button, the volume flow rate calculation, the increment/decrement logic of the manual and automatic controls, and the calculation of the speed in automatic mode.

The startup circuit controls a virtual power coil. This status of this power coil determines whether the rest of the program will operate. Exceptions include the toggle button logic to switch between modes, min/max limits on the volume flow rate setpoint, and the HMI data display.

The VFD startup logic turns on the VFD when the power coil is on and vice versa when the power coil is off. It also resets the VFD setpoint to zero when the power status changes, the stop button is pressed, or the toggle button is pressed.

Setpoint limits are also placed on the volume flow rate setpoint in automatic mode. The setpoint is capped between 0 to 130 cubic in/s. This is the operating range of the volume flow rate control and was determined by analyzing the maximum volume flow rate that could reasonably be obtained with a large cross-sectional area and the maximum conveyor speed.

The toggle button function block takes the button switch input and uses edge detection to produce an on/off signal that corresponds to the selected mode where the toggle coil turned off is manual mode and on is automatic mode.

The volume flow rate calculation function block converts and scales the 8-bit cross-sectional area data from the sensor into a 16-bit integer to represent the data in square inches and uses this data in conjunction with the actual speed reading from the VFD to calculate the volume flow rate.

The increment/decrement logic increases and decreases the setpoints in manual and automatic mode. The user control for the increment/decrement logic is through virtual buttons on the HMI screen.

Calculation of the speed in automatic mode uses a similar concept as the volume flow rate calculation. The volume flow rate setpoint from the user and the cross-sectional area data from the sensor are combined to calculate the necessary conveyor speed.

4.4.2 PLC – HMI

The PLC communicates with the HMI through PROFINET with an ethernet cable. Buttons pressed on the HMI screen changes PLC variables in the program to perform an action. The data displayed on the HMI are PLC variables, namely the current measured volume flow rate, the current speed of the conveyor, and any setpoints if specified. The instruction manual, appendix E gives a detailed discussion of the HMI functions.

4.4.3 PLC – Sensor

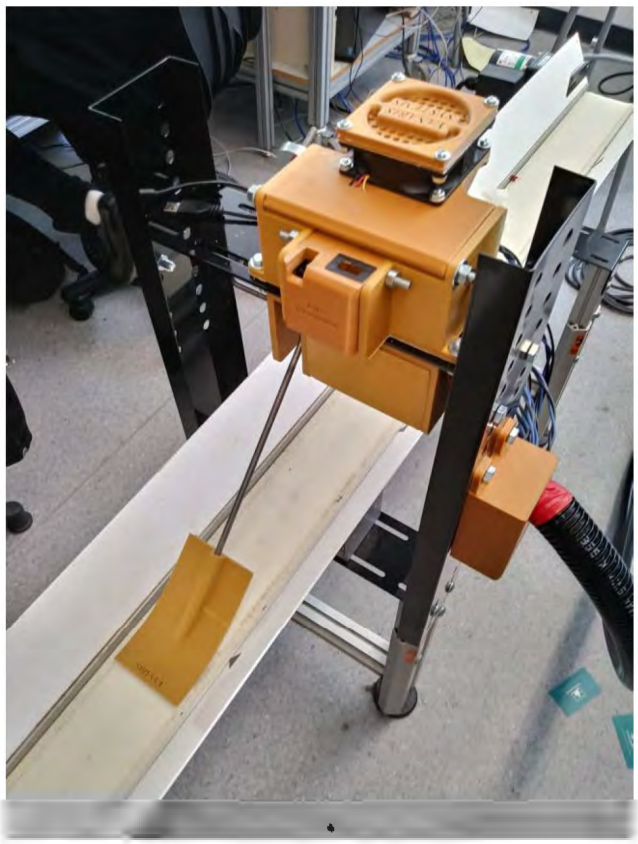

Figure 4-6: Cross-Sectional Area Sensor

A set of relays act as the communication method between the PLC and the sensor. The use of relays allows for the sensor power circuit and the PLC power circuit to be electrically decoupled and provides an extra layer of safety to the PLC. To do this, the microcontroller in the sensor controls the opening and closing of the relay switches and the PLC feeds power through the relays and reads the returned signal. The signal read by the PLC is eight on/off signals through the eight return data wires from the sensor. This acts as an 8-bit data transmission line with a value of 0-255. The PLC program then converts and scales this 8-bit data into a 16-bit integer value that represents the cross-sectional area measurement.

4.4.4 Microcontroller C program

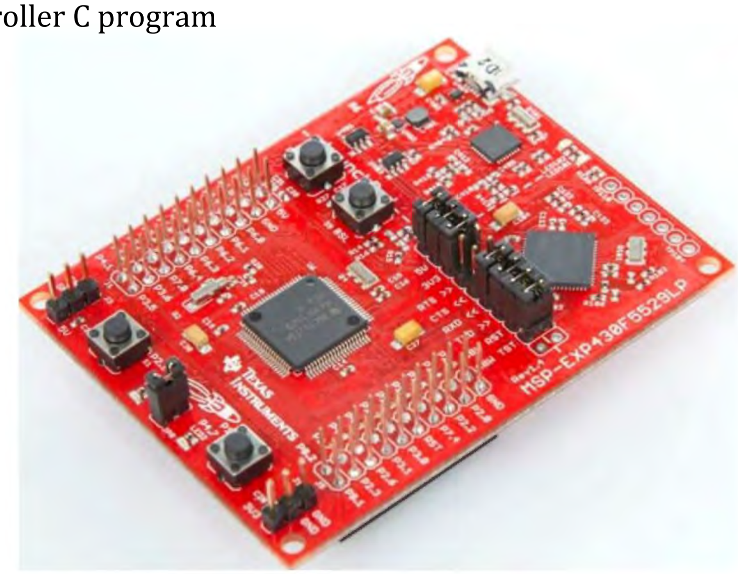

Figure 4-7: MSP-430F-5529 [6]

The microcontroller used is the TI MSP430. C programming language is used to write the code, which can be found in Appendix H.1 Microcontroller C program. The code includes functions to read the potentiometer, convert the voltage reading to a cross-sectional area, and send this result to the relays.

The initialize ADC (analog to digital converter) function is used to enable and clear the conversion bits and tells the ADC where (channel) to read the signal. Another function is then used to tell the ADC to take a reading of the potentiometer.

The main function is a while loop that takes a result from the ADC sample, converts it to a cross-sectional area, and sends this to the output pins that connects to the relays. The calculation to find the cross-sectional area from the height reading can be found in Appendix F.1 Height – cross-sectional area relationship calculation.

4.5 Testing Procedure

The testing procedure was conducted to refine the volume flow rate measurement and the manual/automatic modes of the program. Due to the nature of the project, the prototype cannot be tested using sample cannabis products at the test facility. Also, due to time limitations, testing was used to verify that the PLC and microcontroller program works rather than to increase resolution and accuracy.

4.5.1 Conveyor motor speed

Testing involved running the conveyor motor at various speeds to identify its workable range. This gave a quantifiable relation between user input through the HMI and linear speed of the conveyor. The data collected is shown in Figure 4-8. This test was able to confirm reliable control of the conveyor motor speed using a linear conveyor speed assumption.

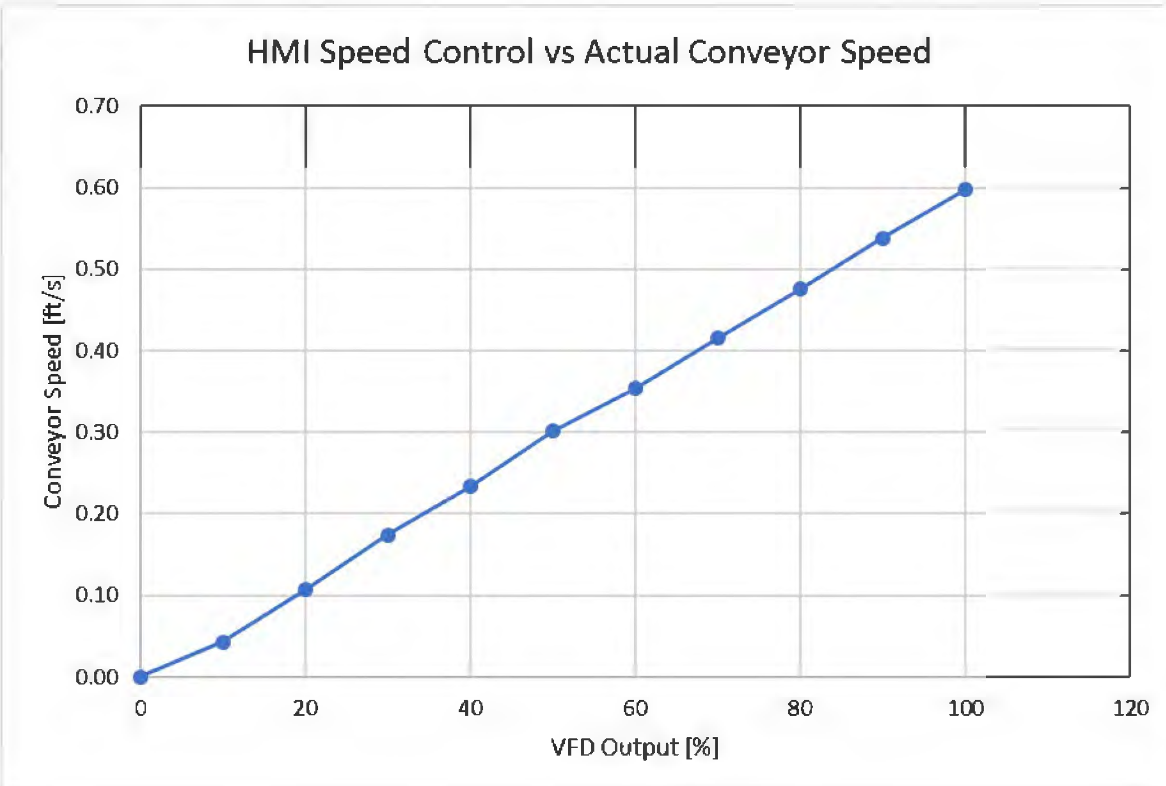

Figure 4-8: Speed linearity response test.

4.5.2 Level Sensor test

Testing of the level sensor allowed the team to identify the workable range of the potentiometer. Since the project only aims to test the concept rather than produce very accurate results, rough estimates were used to accelerate the testing process.

The potentiometer's working range was used to identify the mounting position of the paddle to make sure it covered the entire depth of the conveyor.

Figure 4-9: Potentiometer Coupled to Hight Measurement Paddle

An estimate of the conveyor's cross-sectional shape was used to relate the height measurement reading to the cross-sectional area.

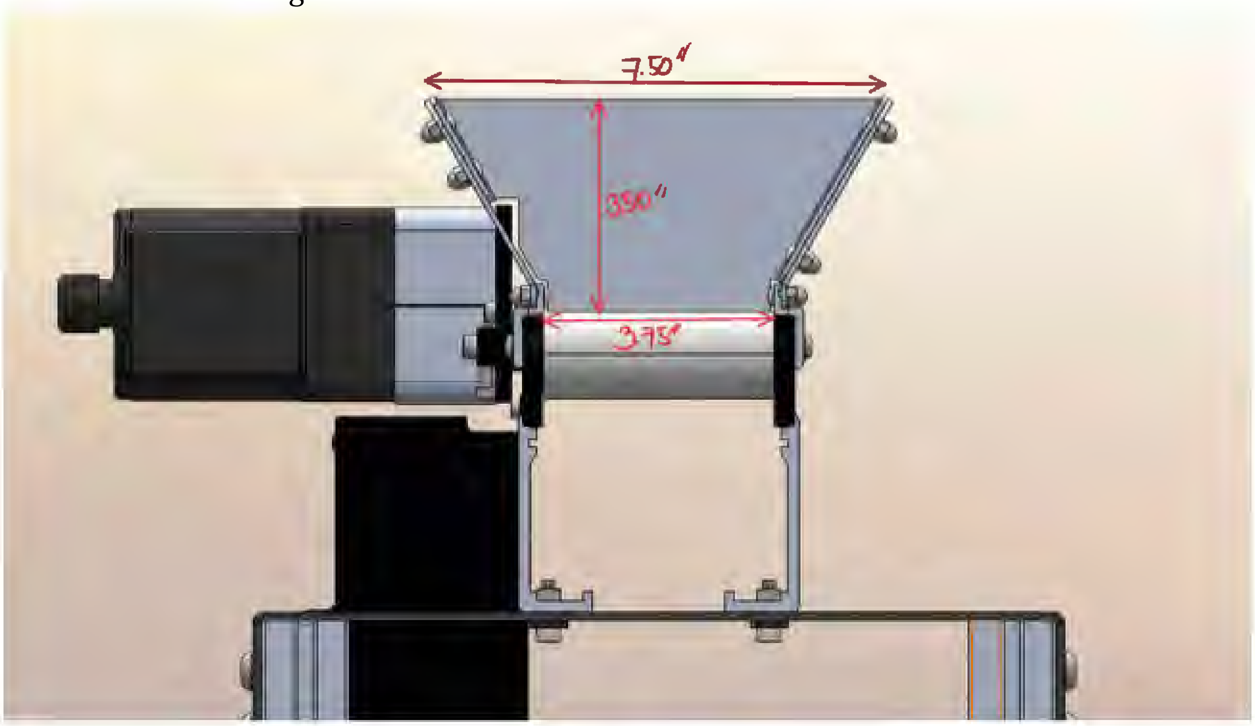

Figure 4-10: Conveyor Cross-Sectional Area

Appendix Section F.1 Height – cross-sectional area relationship calculation, shows a detailed calculation of the height and cross-sectional area relationship. Since the potentiometer resolution is much greater than what is needed to estimate the height, a one-time calibration can be done once the sensor is securely mounted to the machine. A recalibration is only necessary if the sensor has been moved between set-ups or when mounting a new sensor. Future work on the sensor and its resolution will be discussed in a later section.

5 Discussion of Results

5.1 Volume Flow Rate Measurement

In order to meet the objective of obtaining a volume flow rate reading of material on the conveyor, two parameters were needed: conveyor speed and the material's cross-sectional area. The team's original design included a laser scanner as the measurement tool to measure the material's cross-sectional area. However, due to unforeseen budgetary changes, the laser scanner was unavailable to the team for use on this project and an alternate measurement device was needed.

A brainstorming session led the team to consider a mechanical level sensor that would approximate the cross-sectional area of material on the conveyor. The sensor would need to be able to detect the height changes on the material passing under it as the conveyor moves. Upon research of the available mechanical level sensors on the market, it became apparent that the available mechanical sensors were binary on-off level switches and would not be sufficient for this project. To overcome this difficulty, a mechanical level sensor would need to be designed and prototyped to complete the project objectives.

The sensor designed for this project utilizes a rotating potentiometer that is connected to a lever that rests on the conveyor material. The voltage drop through the potentiometer is measured and processed by a microcontroller with an analog to digital converter. The data signal that represents the cross-sectional area of material on the conveyor is then sent in digital form to the PLC.

Several aspects of the sensor were designed using data from tests performed by the team. During preliminary testing of the mechanical sensor, it was observed that as the sensor arm contacted the product, the force from the contact would hold up the material on the conveyor and create resistance to the material passing under the arm. To fix this problem, a counterweight system as shown in Figure 5-1, was designed to balance the force on the material from the sensor. This counterweight system was sufficient in removing the resistance to passing material.

Test results to measure volume flow rate were successful and the volume flow rate data has been incorporated into the PLC program.

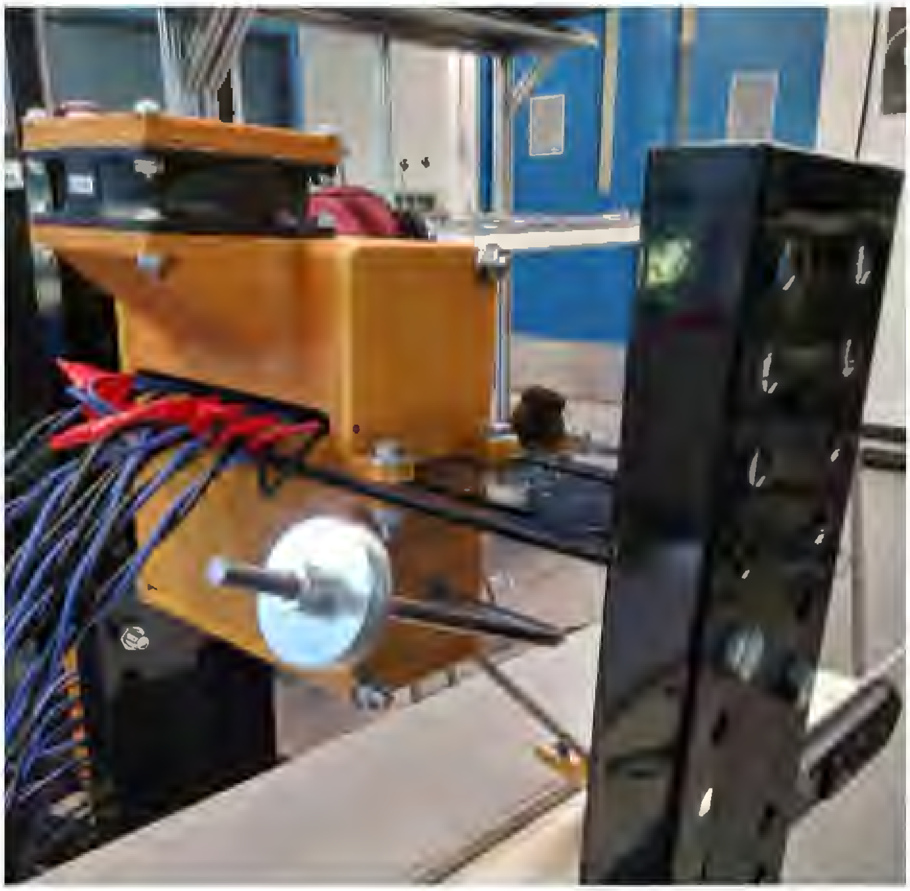

Figure 5-1: Counter Weight

5.2 Manual and Automatic Control

In order to obtain manual and automatic control of the conveyor, the team needed to complete interfacing of all the provided electronic components. After some delay with the electrical commissioning, the team was able to achieve control of the VFD. This was a major milestone as it meant the electrical portion of the project had been completed and that the remaining work needed to achieve manual control was software programming.

Manual control of the conveyor functions by reading a user setpoint from the HMI, then relaying this setpoint to the VFD. The volume flow rate that's displayed in manual mode uses speed data from the VFD and area data from the mechanical sensor. The VFD provides the actual speed of the conveyor but is output as a unitless number. The PLC program uses the conveyor motor test results shown in Figure 4-8 to convert this into units of ft/s in order to calculate the volume flow rate. The resulting manual control logic allows the user to vary the conveyor speed while monitoring the volume flow rate, which is displayed on the HMI.

Automatic control of the conveyor encountered some difficulty with the interfacing between the custom built mechanical sensor and the PLC. While Siemens electronics communicated with each other over ethernet, the team decided not to pursue this type of communication for the sensor due to budget constraints and time limits. Initially, the team proposed communicating with an analog signal. However, it quickly became apparent that this would not work. In order to obtain a measurement from the sensor, the team needed to measure the voltage drop across the potentiometer. The analog input on the Siemens PLC provided was designed to read analog current. The solution that the team decided upon was to include a microcontroller as part of the sensor that would calculate the area measurement then operate a relay to send data to the PLC. This solution was bulky and required many wires (10) to run between the sensor and the PLC. However, the team decided that it was an acceptable tradeoff in return for a reliable communication method and was appropriate for a proof of concept design. The finished automatic control logic allows users to input a volume flow rate setpoint and automatically adjust the conveyor speed to achieve the setpoint. This allows the conveyor to output a constant volume flow rate even with varying levels of material on the conveyor.

The results of the manual and automatic control software were successful and met the projects objectives.

5.3 Difficulties and Lessons Learned

5.3.1 Electrical

One of the biggest road blocks encountered by the team was the commissioning of the electrical components. The first milestone for this project was to assemble a working test bench. This included assembling the components of the control box from scratch and wiring all the electronic components. Although the team had been briefly introduced to PLC ladder logic programming before, the team had little background in the commissioning of the components together.

Power wiring and signal wiring was successfully achieved. Research had to be done to determine proper component mounting and positioning in the control panel. For example, laying out components running on DC power in the same row and beginning the row with its own circuit breaker. Spending time learning how to properly mount these components allowed the team to quickly troubleshoot during the wiring process.

However, upon power up of the VFD, problems were encountered with the firmware of the components. After a lengthy diagnosis of the problem, it was determined that the components had to be manually updated to be compatible with the programming platform Siemens was using. The team received support from the product suppliers, E.B. Horsman and Son staff to help commission the electronics.

5.3.2 Sensors

The team initially created the project schedule based on the assumption that the laser scanner would be available for testing. However, due to budget constraints and time limits on the laser scanner demo, there was insufficient time to successfully establish communication between the laser scanner and the PLC. The team therefore had to design and prototype a level sensor with the remaining project time.

Although the team was able to design and prototype a working level sensor, unforeseen circumstances like these should be expected. The project schedule was designed to have ample time to accommodate roadblocks, that eventually led to the timely completion of the project.

Conclusion

The KYLA Engineering team was able to complete the project goals as defined by Keirton for a system that can control a conveyor to produce a constant volume flowrate. The background of this design originates from the fact that the trimmers produced by Keirton run at peak efficiency when they are constantly filled with the correct amount of material by the infeed conveyor.

To complete the design objective, the team designed a mechanical level sensor which utilized a potentiometer coupled to a rotating arm that rests on top of the material flowing on the conveyor. The voltage drop over the potentiometer was processed by a MSP430 microcontroller with an analog to digital converter. The digital signal was used to calculate the cross-sectional area of the material on the conveyor using the geometry on the conveyor. The cross-sectional area is then sent to the PLC as an 8-bit binary number.

The engineering team experienced unexpected difficulties throughout the course of the project that ultimately shaped the final result. Firstly, the need for an original sensor design was introduced to the project scope after it was determined that a laser scanner would not be included in this project. The sensor design took up a large portion of the project time as communicating with the PLC proved to be a difficult task. The team was able to overcome this hurdle by using the skills they learned in previous courses to integrate microcontroller technology into the project. Another difficulty the team overcame was the testing of the level sensor. Testing of the level sensor with actual marijuana was not feasible, hence pinecones were used to simulate the leafy material. Testing with the pinecones revealed that due to the light nature of the leafy material, the material tends to get stuck as it attempts to flow under the level sensor paddle. The team overcame this challenge by designing a counter weight which reduced the pressure exerted by the paddle. This allowed the material to flow freely under the paddle.

The project completed by the engineering team is a proof of concept that a conveyor can be controlled to achieve a constant volume flow rate setpoint. In the future many modifications can be made to this project and apply what was developed in many different applications. A recommended modification to the existing sensor design would be to create a serial communication interface between the microcontroller and the PLC. This would require PLC knowledge and experience that is beyond the KYLA Engineering team.

The volume flow rate control system for a conveyor developed by KYLA Engineering proves the concept that a constant volume flowrate setpoint can be used to control a conveyor belt. The use of a physical sensor strikes an appropriate balance between cost and accuracy and works well with leafy organic material.

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Appendices

A. Request for Proposal

B. Project Management Items

C. Manufacturing Drawings

D. Circuit Diagram

E. Instruction Manual

F. Other Related Material

G. Design Review Package

H. Computer Codes

A. Request for proposal

Twister Trimmer Conveyor Automation

October 16, 2018

Issued by:

Keirton Inc.

10425 173 St. #109, Surrey, BC V4N 5H3

Keirton Representative: Chadley Michaluk, P. Eng.

(604) 495-1895 ext 712

chadley@keirton.com

Introduction and Background

Keirton Inc. designs and manufactures agricultural machines based in Surrey, BC. Founded by Jay Evans 10 years ago, they have now a successful line of product called the Twister Trimmer. A leading competitor in the industry, the company is well known not only for the Twister Trimmer line but for their quality of customer service.

The purpose of this Request for Proposal is to find a qualified design team to add on new features on one of the Twister line of products-Twister Conveyor.

Project Description and Scope

Keirton is seeking a design team that will help automate the current Twister conveyor design and allow customers to log and track material going through the conveyor and to adjust various parameters to achieve desired feed rate. The selected team will be responsible for providing a detailed design that can be retrofitted to the current conveyor system and implemented in the current PLC program that controls conveyor motors.

Deliverables include but are not limited to:

- BOM for any off-the-shelf components
- Manufacturing drawings for any custom mechanical parts
- PLC program to run the system
  - Allow user to adjust parameters to achieve desired volume flow rate
  - Allow a set of parameters to be saved as a specific 'recipe'
- Proof of concept: integrate design and code to current product through a prototype

Anticipated Selection Schedule

Project completion date is May 2019. Earlier or later dates may be proposed and will be evaluated accordingly.

Request for Proposal:	October 16, 2018
Selection of Top Bidders/Notification to Unsuccessful Bidders:	October 23, 2018
Start of Negotiation:	October 25, 2018
Contract Award/Notification to Unsuccessful Bidders:	October 30, 2018

Time and Place of Submission of Proposals

The RFP is available at Keirton.com/Info. It can be viewed or downloaded by Tuesday, October 16, 2018 8 am.
Responses to this RFP must be submitted to the contact person listed above and should be named "RFP – Twister Conveyor" by October 20, 2018.

Timeline

The project needs to be completed by May 2019 – 7 months from awarding of contract.

Elements of Proposal

The project bidders are to submit a proposal that includes the following general information:

- Background of the firm/team. This should include credentials of each member, as well as the total number of individuals that will take on of the project.
- Previous experience that relates to the projects as well as other strengths that will distinguish the project team. Provide a list of related projects, including examples of work.
- Technical proposal of no more than 20 pages. It should include an overview of proposed solution, proposed schedule and milestones, and cost proposal.

Evaluation Criteria

Design teams submitting a proposal should meet the following criteria:

- Experience working in the agricultural/pharmaceutical equipment industry.
- Technical expertise in component design and integration.
- Technical expertise in control and instrumentation.
- Proven success record of staying on budget and meeting set deadlines.

Possible Roadblocks

The machines are designed to service cannabis industry, which may conflict with personal values. On the same note, sufficient background on the physiology of cannabis is essential in the design process. Geometry specifications of the existing conveyor system will be provided as a SolidWorks model and it is expected that delivery of the final design will be in the SolidWorks model and drawing filetype.

Budget

The budget for the project is $40, 000. This includes any prototyping needed to prove concepts.

Yana Burgos
Kyle Manson
Stephen Yu

B. Project management items

B.1 Responsibility Assignment Matrix

B.2 Milestone Schedule

B.3 Technical Requirements

B.4 Project Work Breakdown Structure

B.5 Project Schedule

B.1 Responsibility assignment matrix

Responsibility Assignment Matrix A - Accountable, R - Responsible, C - Consult, I - Inform		Project Team Yana	 Stephen	 Kyle	Project Sponsors Chadley	 Adam
Work Bench	Control Panel Stand: Design and Manufacture	**A**	R	R	C	I
	Set-up: Assembly and Wiring	**A**	R	R	I	C
	Verify: Speed control of motor using PLC	**A**	R	R	C	I
Design	Evener Mechanism	R	R	**A**	C	I
	Volume Flow rate measuring	R	R	**A**	C	I
Software	Volume Measurement	R	**A**	R	C	I
	Motor speed control	R	**A**	R	C	I
	Evener Control	R	**A**	R	C	I
	HMI	R	**A**	R	C	I
Testing	Volume measurement	**A**	R	R	C	I
	Evener design test	R	R	**A**	C	I
	Volume/Conveyor Speed control	R	**A**	R	C	I
Reports	Final technical report	**A**	R	R	I	C
	Manufacturing Drawings	R	R	**A**	I	C

Figure B.1: Responsibility assignment matrix.

B.2 Milestone Schedule

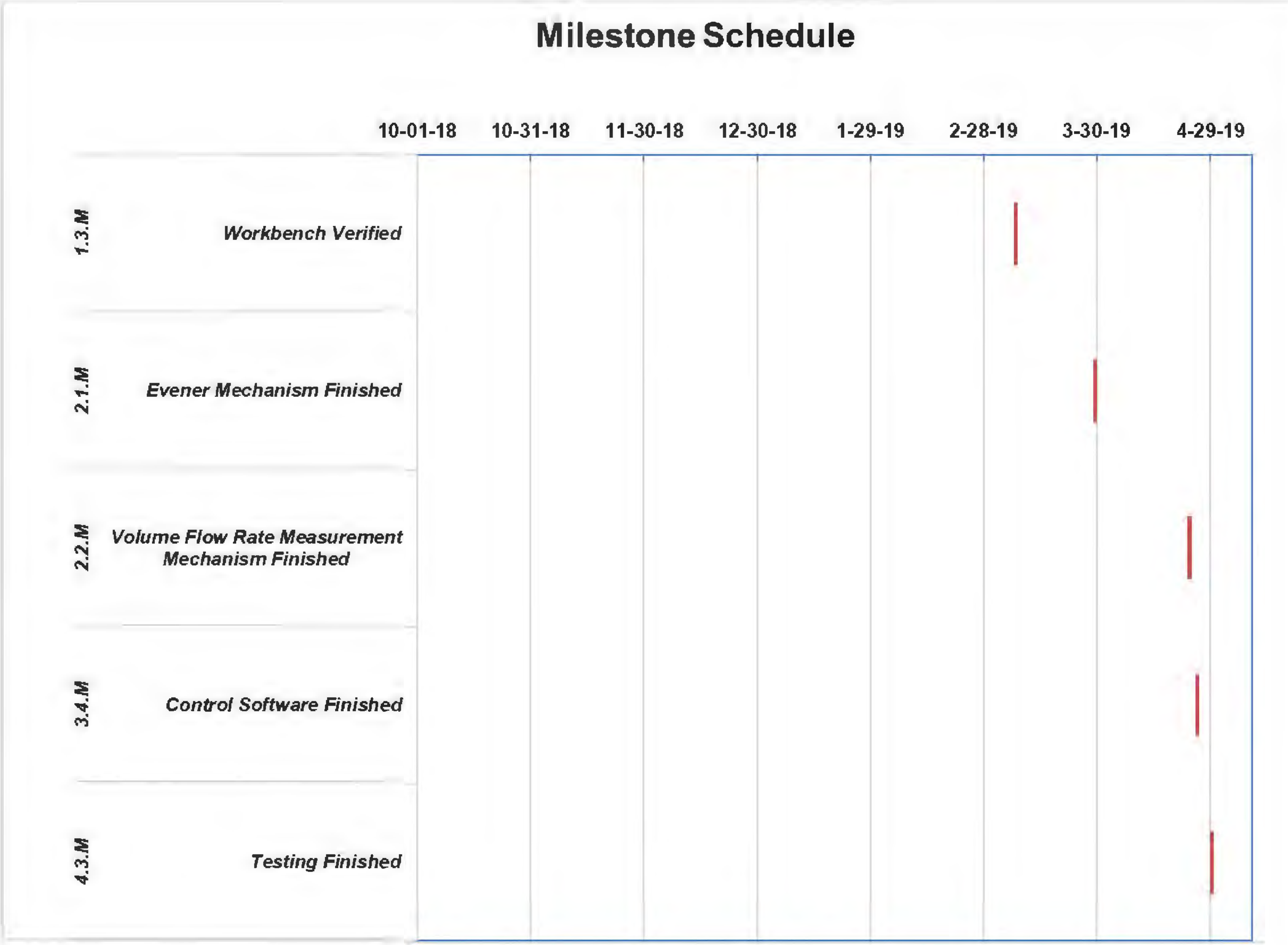


Figure B.2: Milestone Schedule

B.3 Technical Requirements

Electrical

Use Keirton specified electrical components – Siemens products

Produce instruction manual for control panel operation

Mechanical

Sensor should mount on current conveyor assembly. Any modifications should be doable with hand tools and be minimal

Sensor should communicate with Siemens PLC

Document all manufacturing drawings

Provide complete Bill of Materials

Software

Use Siemens programming platform

All program code should be documented and released with project

B.4 Project Work Breakdown Structure

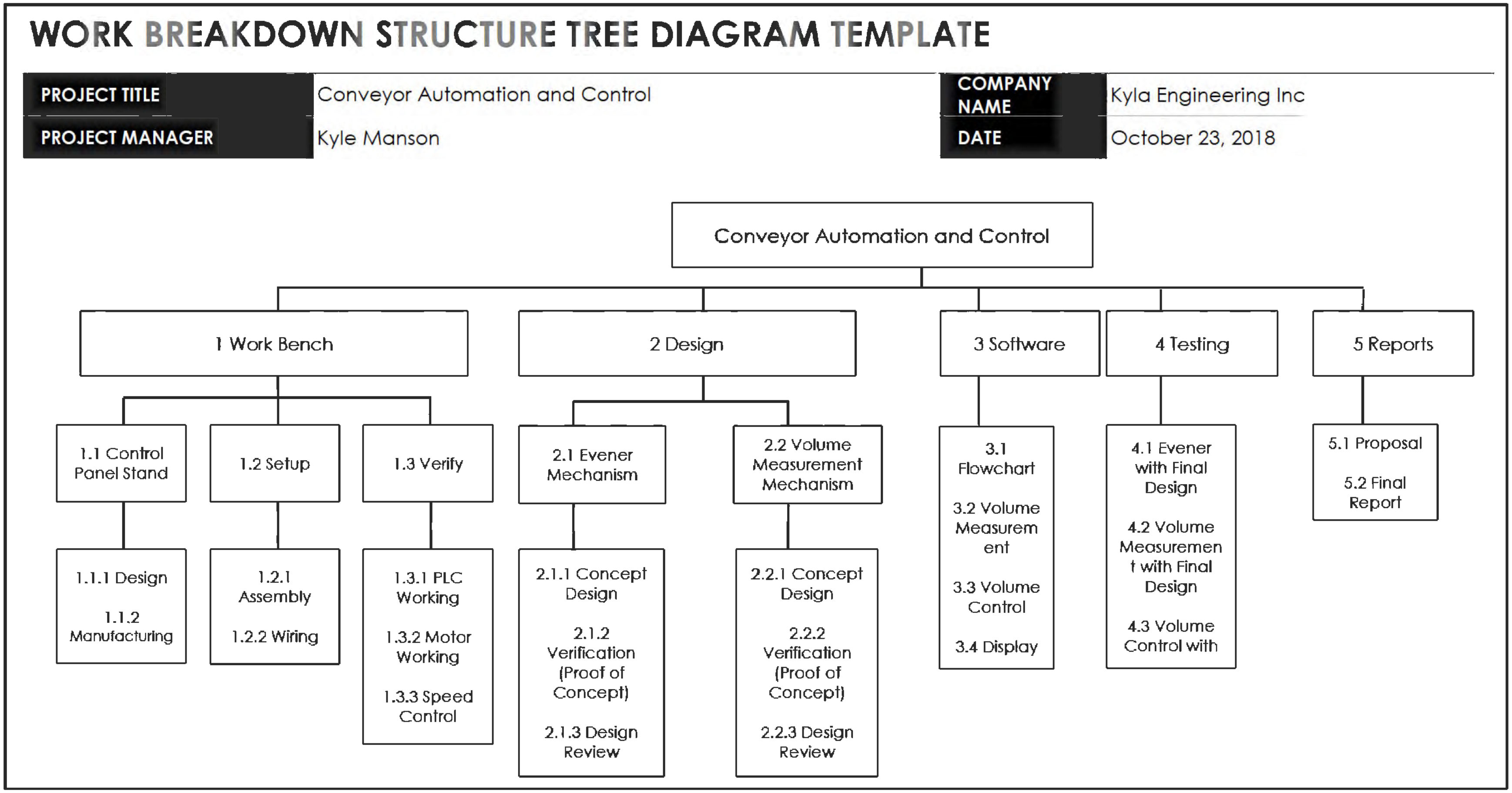


Figure B.3: Work breakdown structure diagram.

B.5 Project Schedule

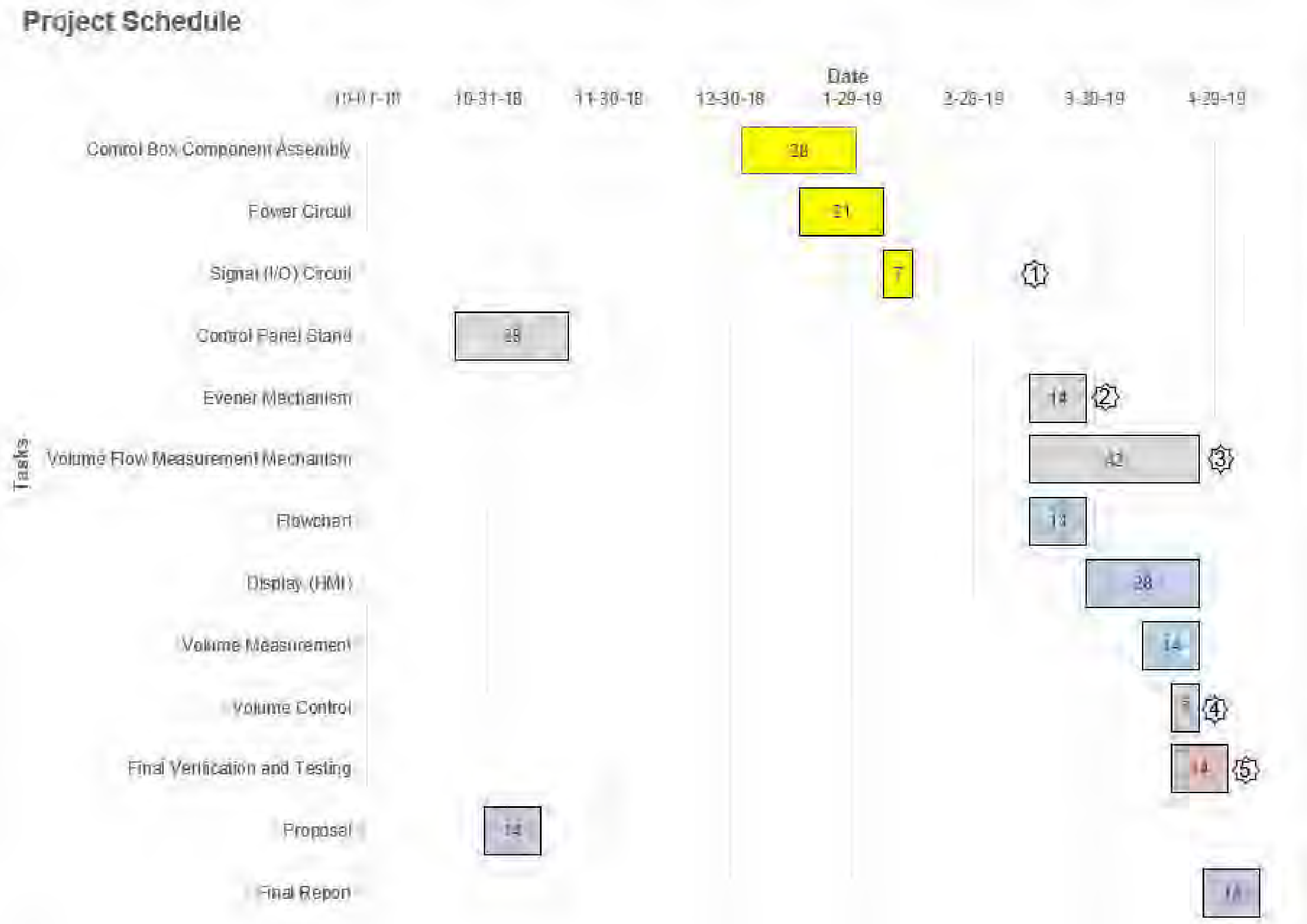


Figure B.4: Project schedule.

C. Manufacturing drawings

C.1 Control Panel Stand

C.2 Sensor Mount

C.3 Sensor

C.1 Control Panel Stand

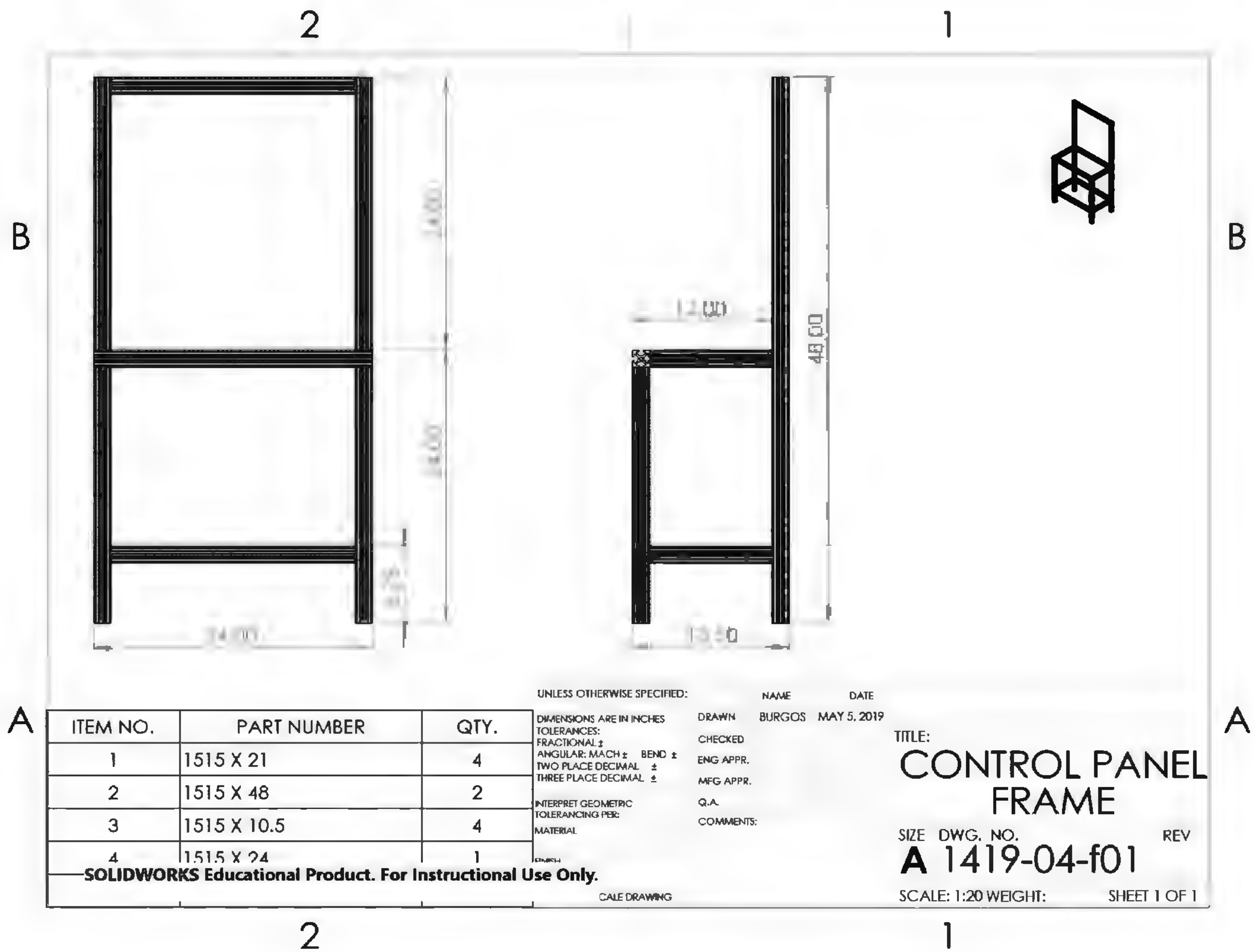


Figure C.1: Control Panel Frame

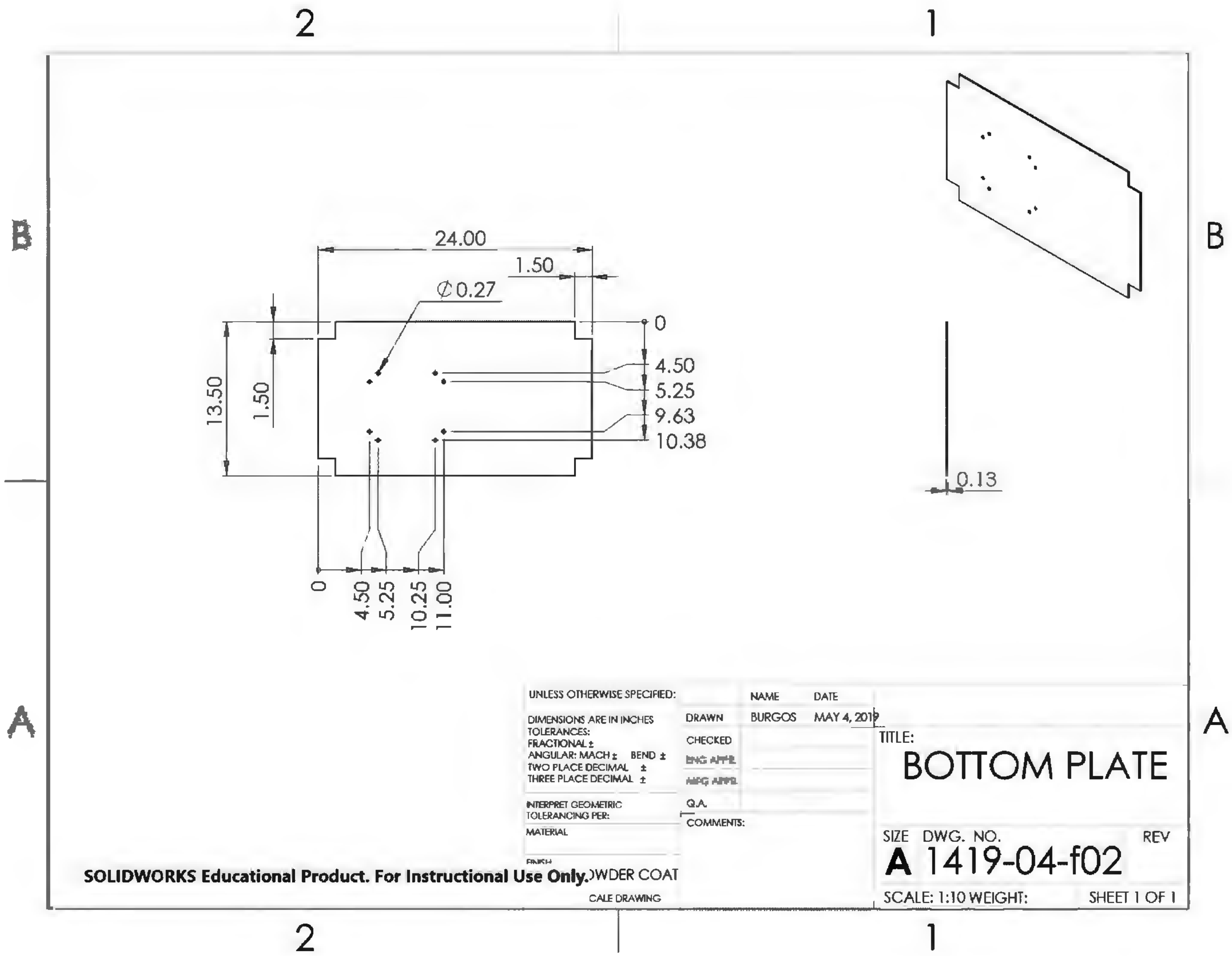


Figure C.2: Bottom Plate

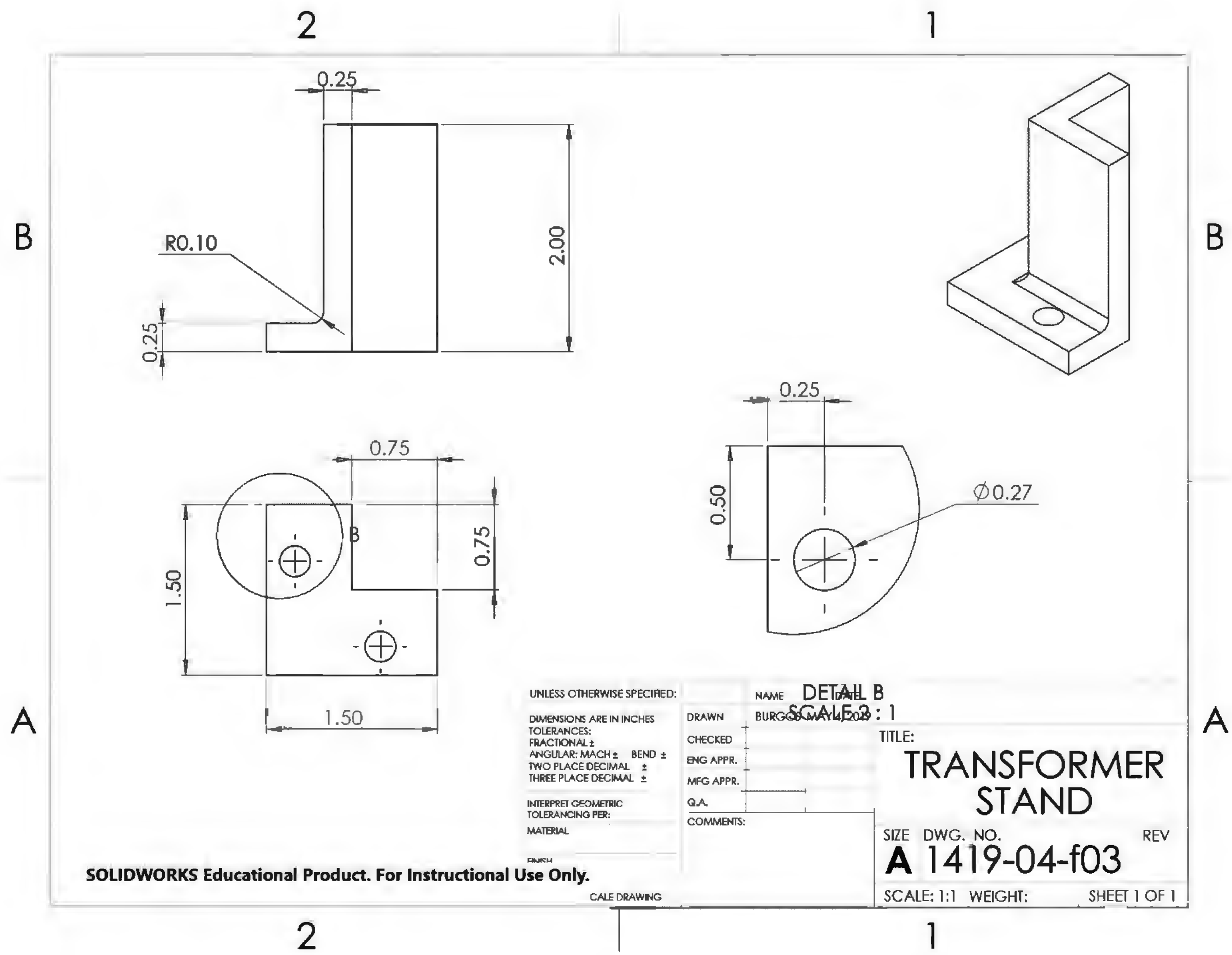


Figure C.3: Transformer Stand

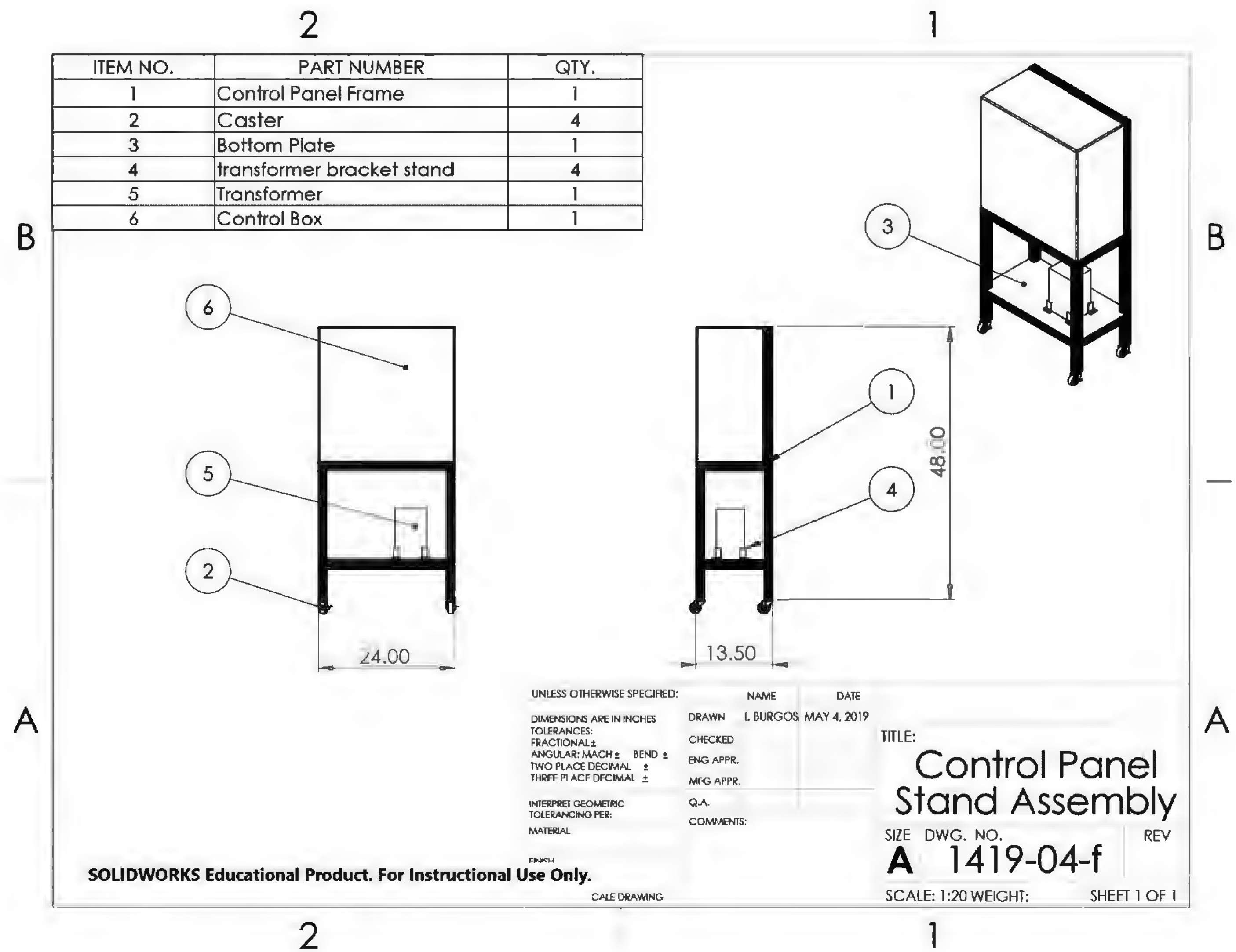


Figure C.4: Control Panel Stand Assembly

C.2 Sensor Mount

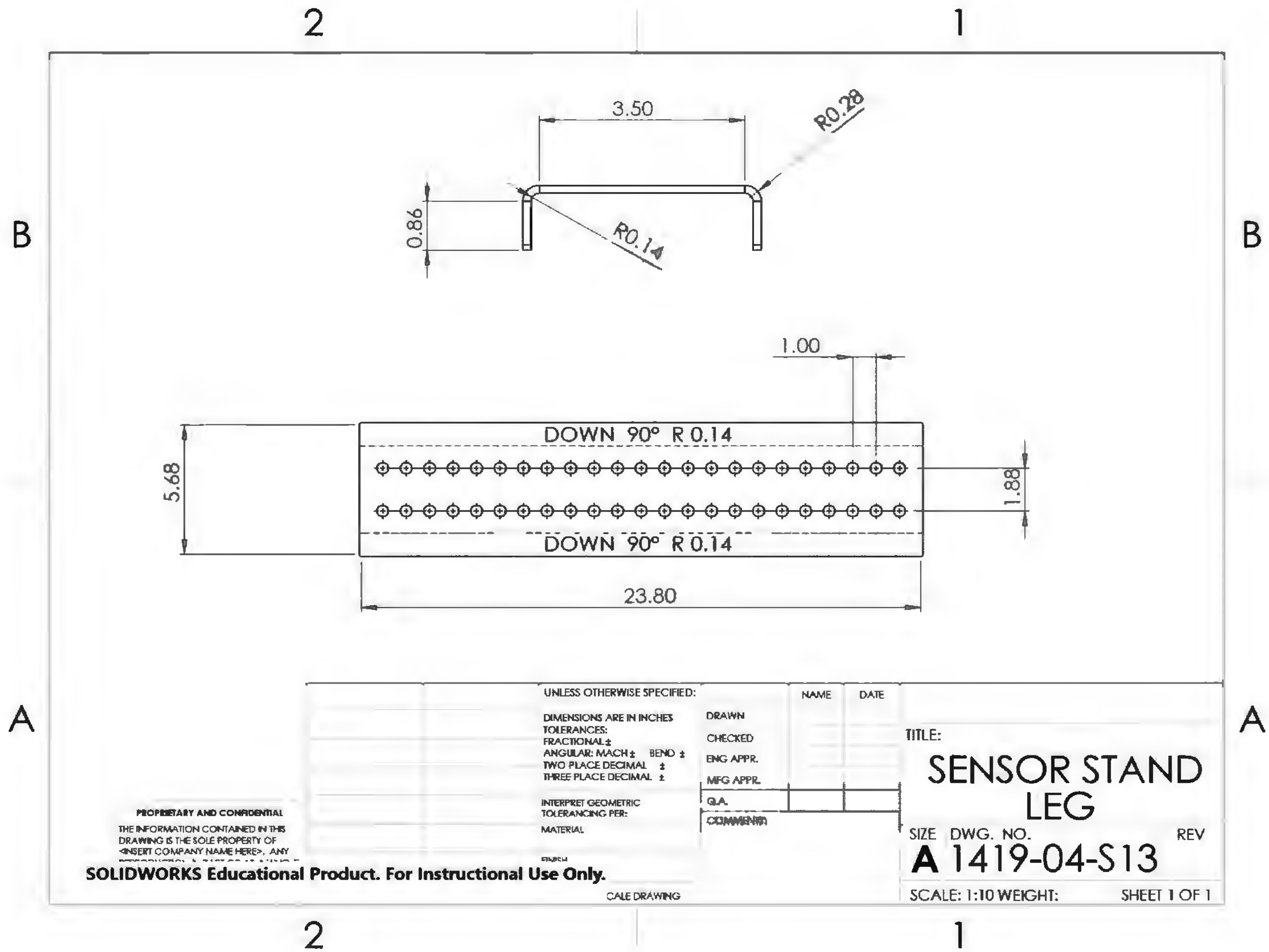


Figure C.5: Sensor Stand Leg

C.3 Sensor

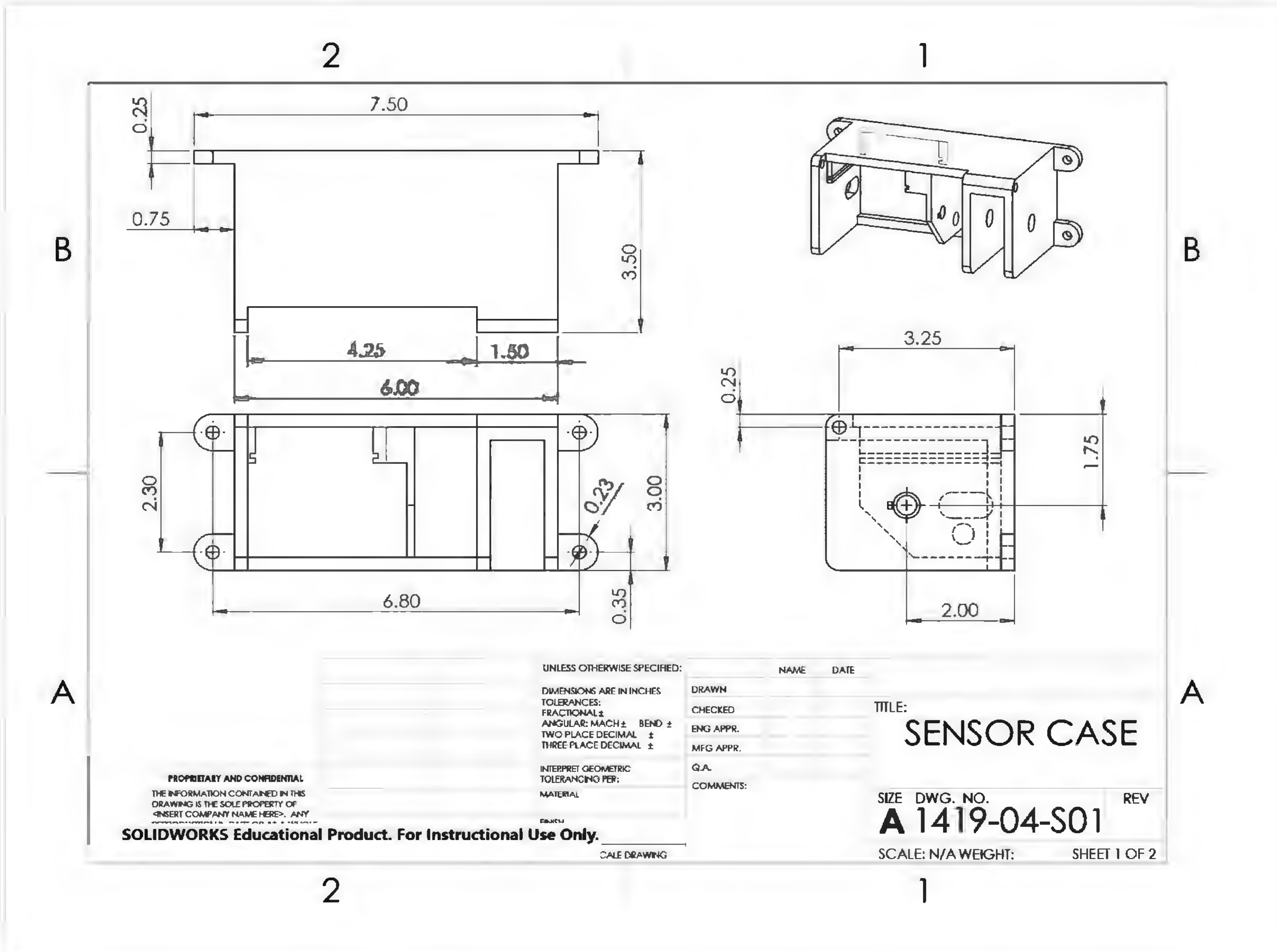


Figure C.6: Sensor Case

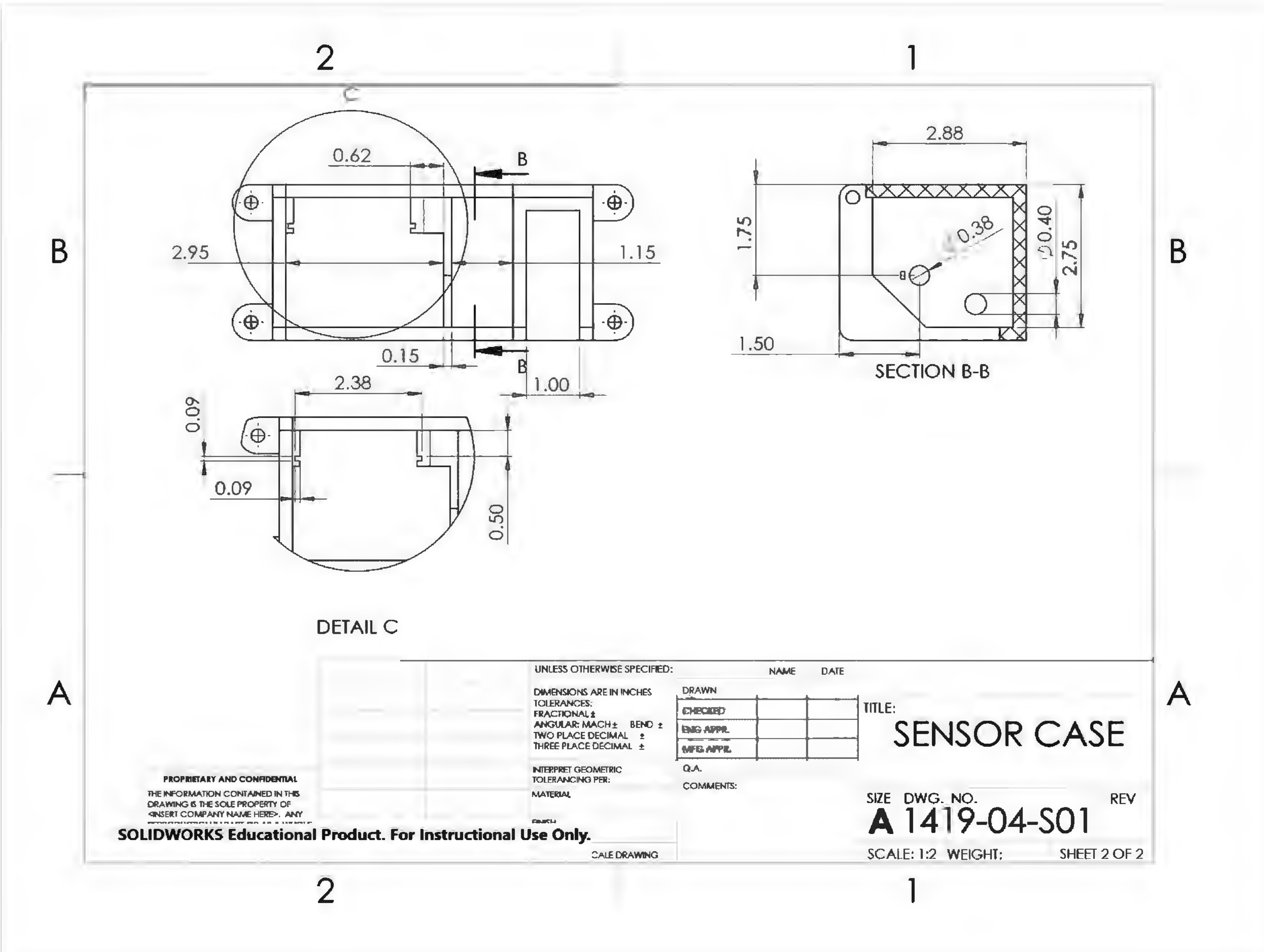


Figure C.7: Sensor Case

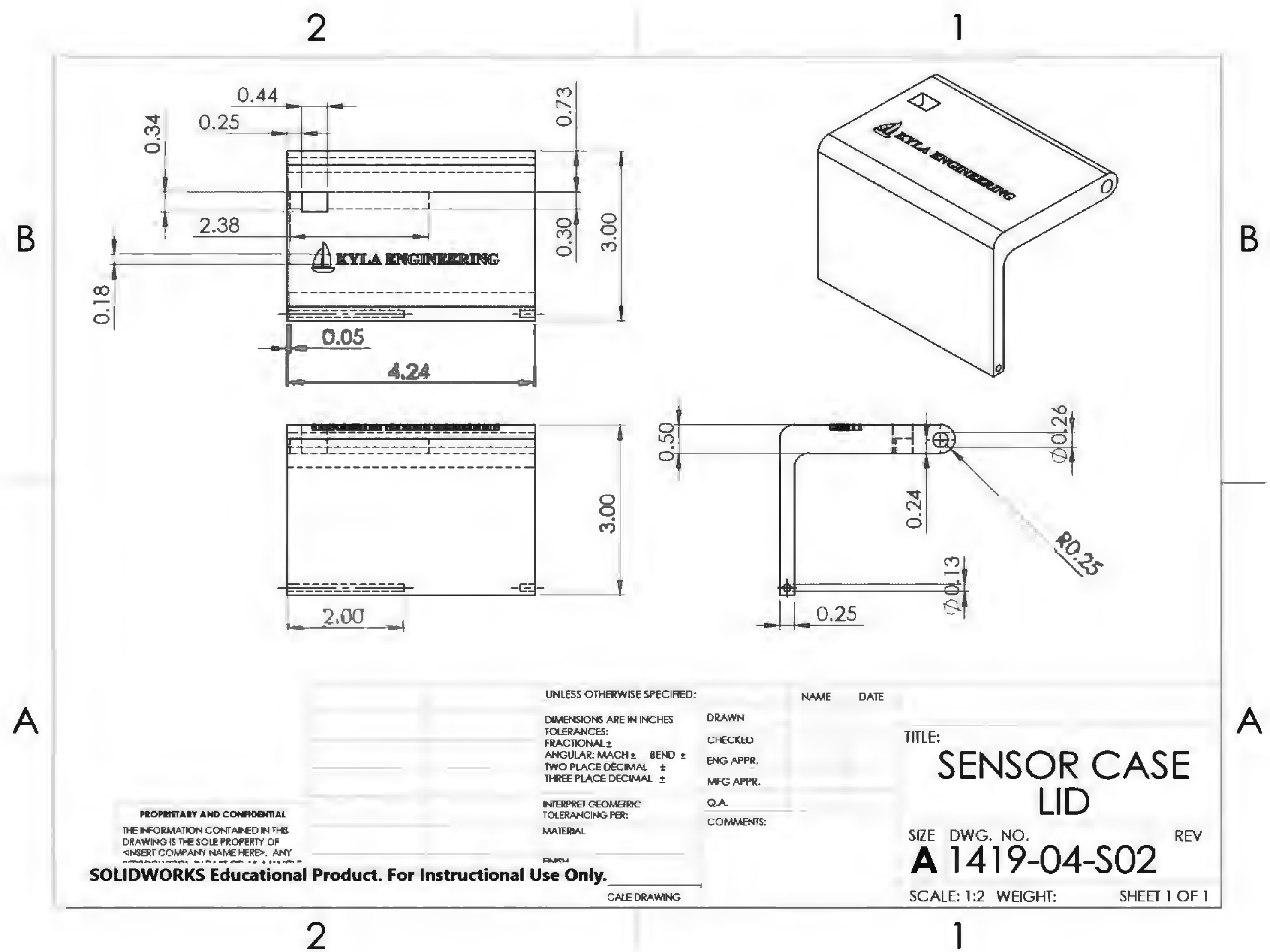


Figure C.8: Sensor Case Lid

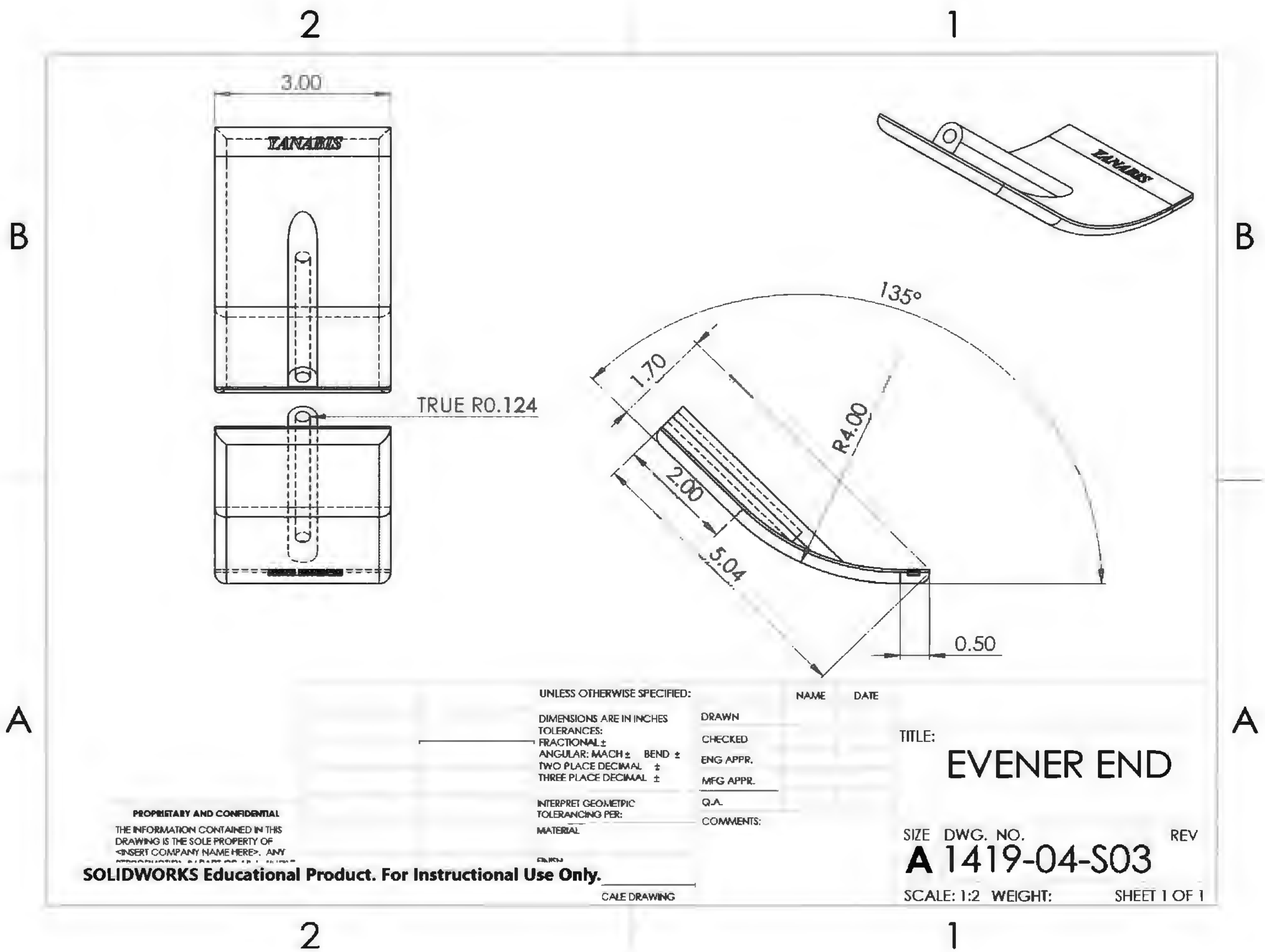


Figure C.9: Evener End

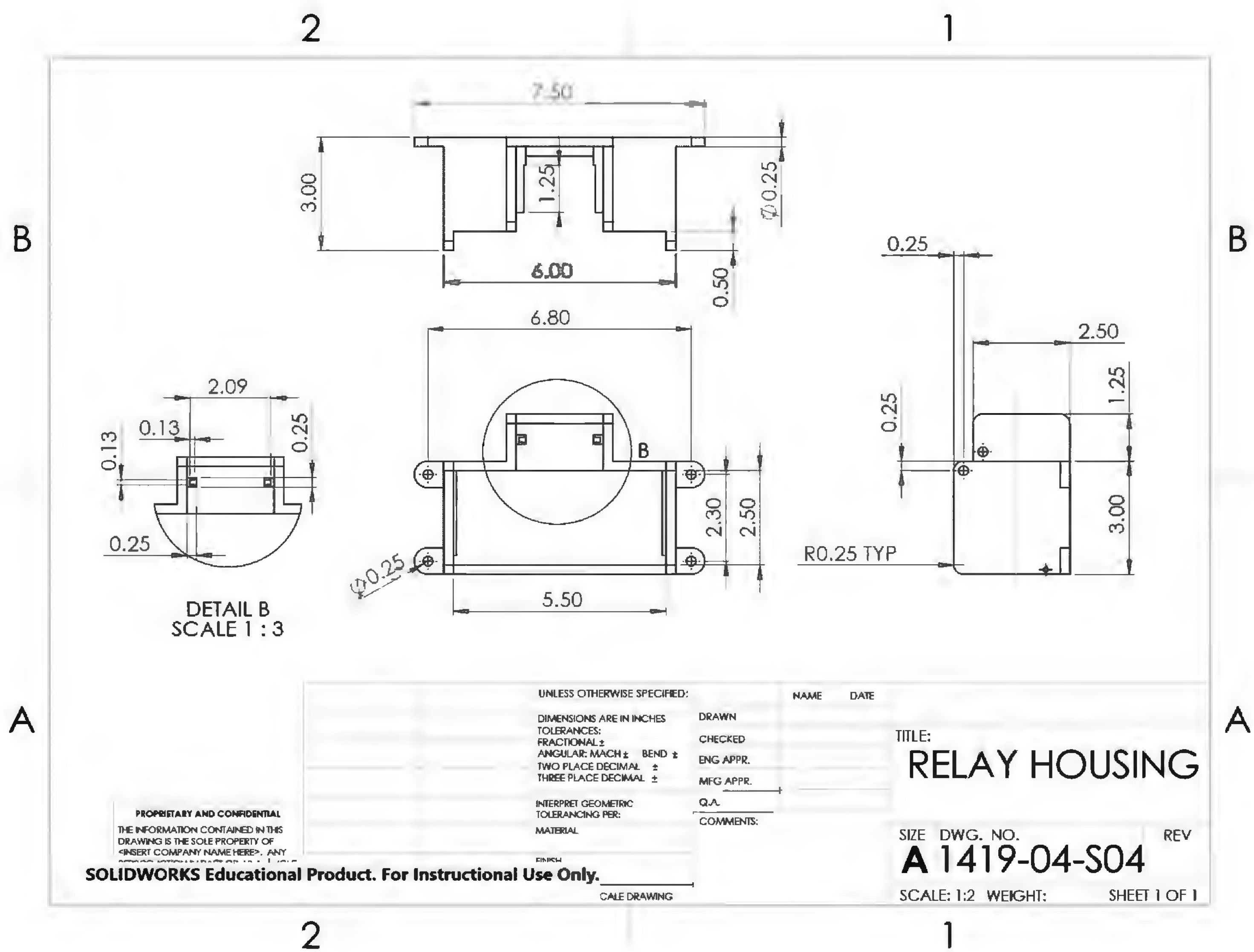


Figure C.10: Relay Housing

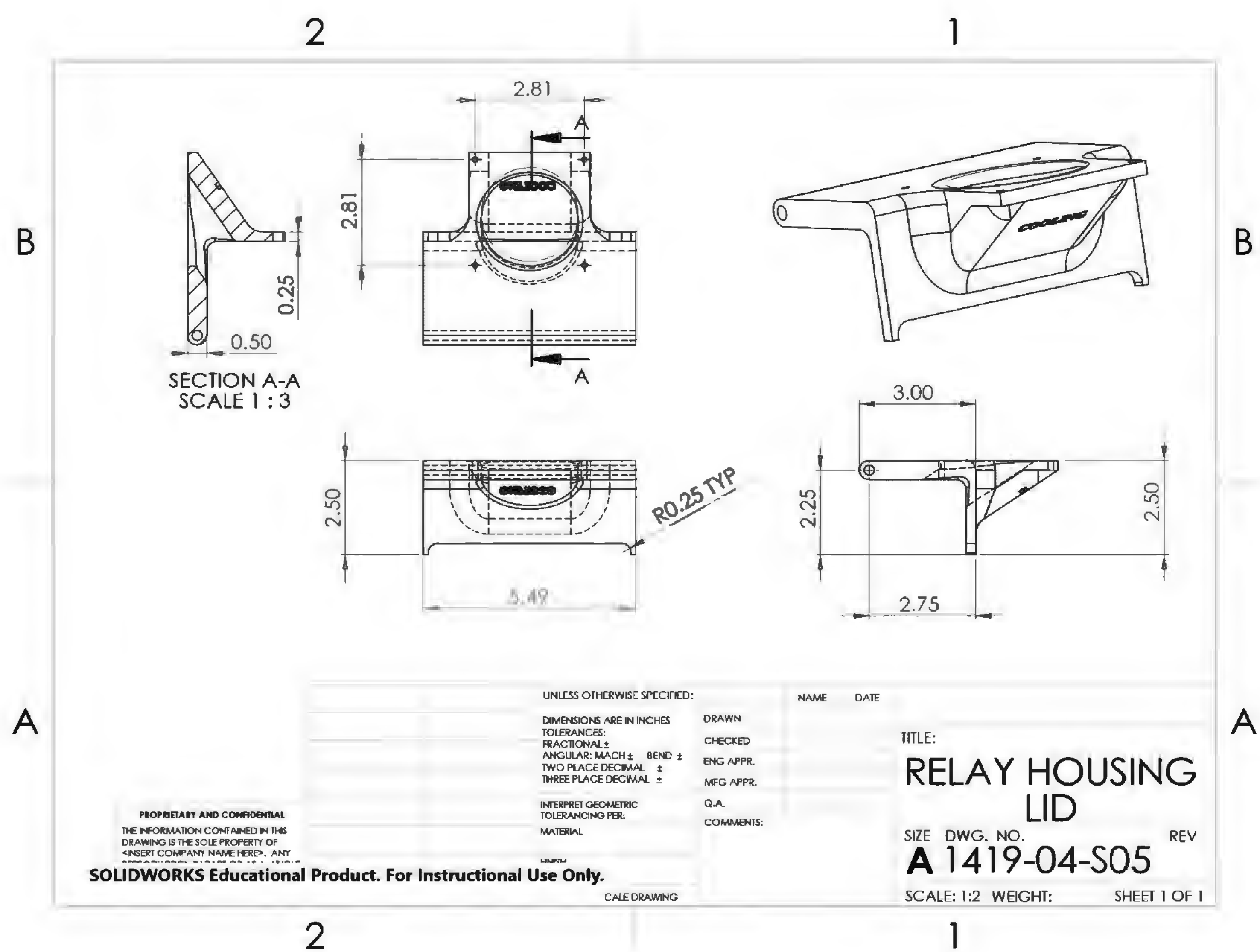


Figure C.11: Relay Housing Lid

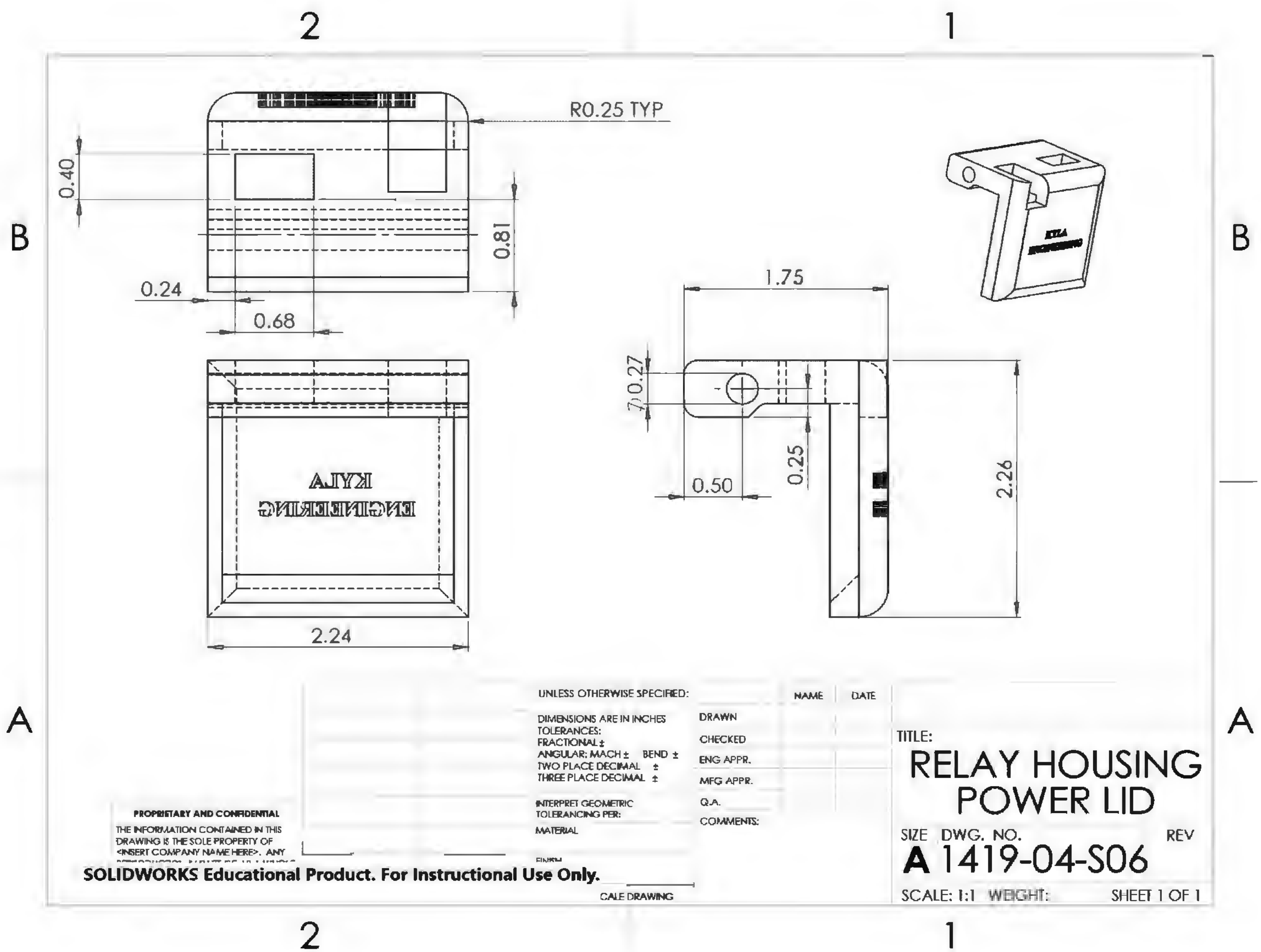


Figure C.12: Relay Housing Power Lid

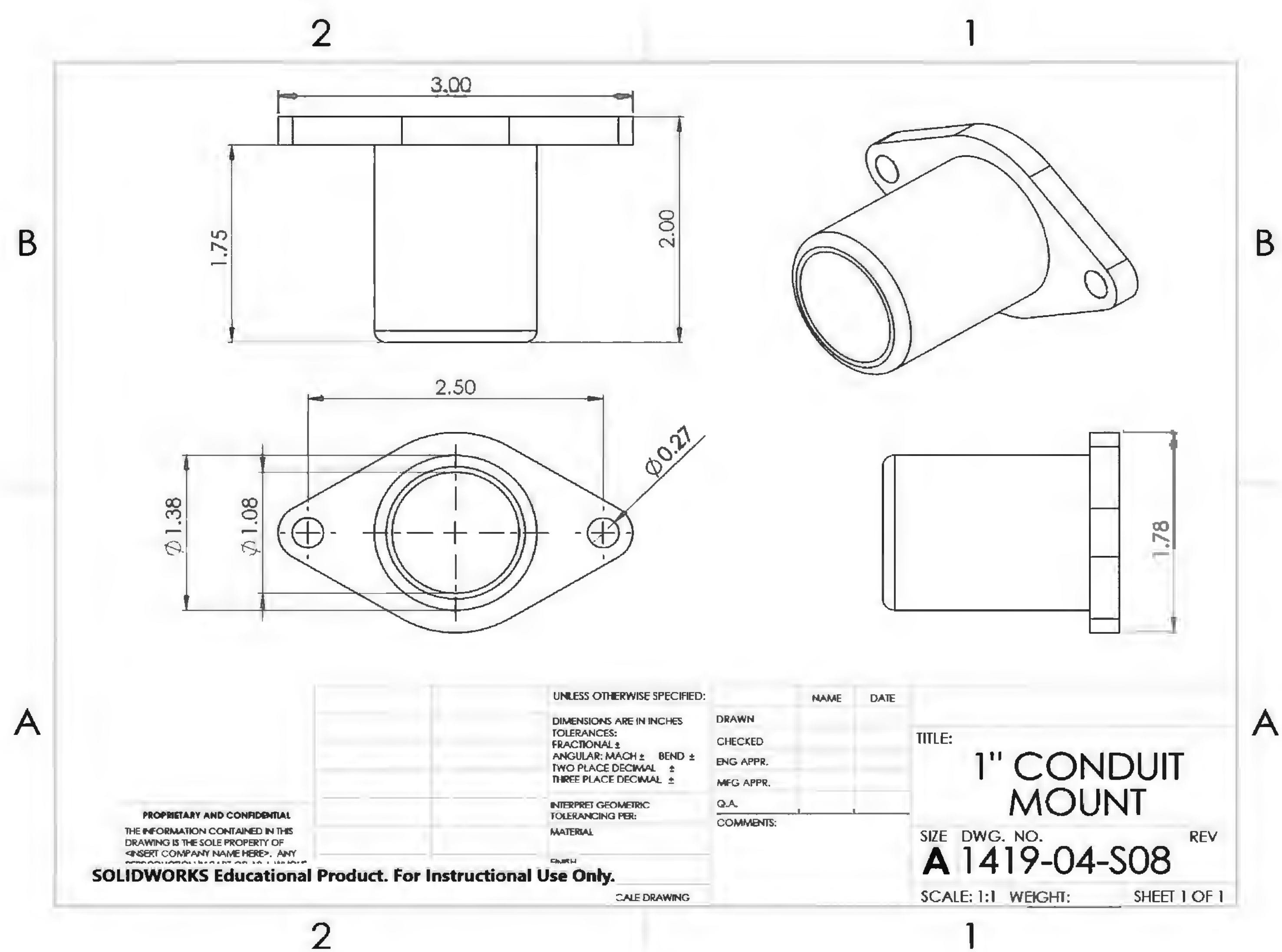


Figure C.13: 1" Conduit Mount

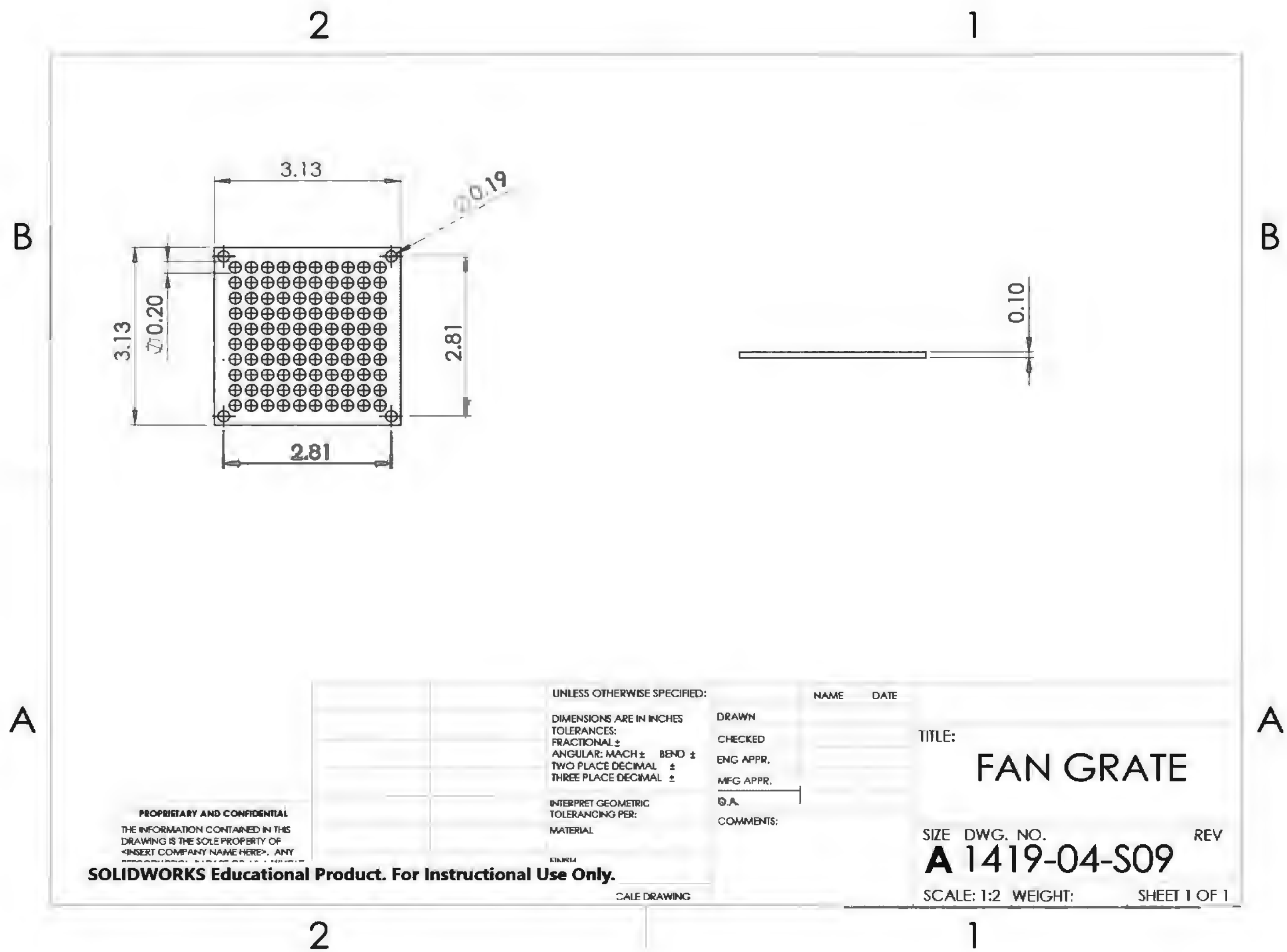


Figure C.14: Fan Grate

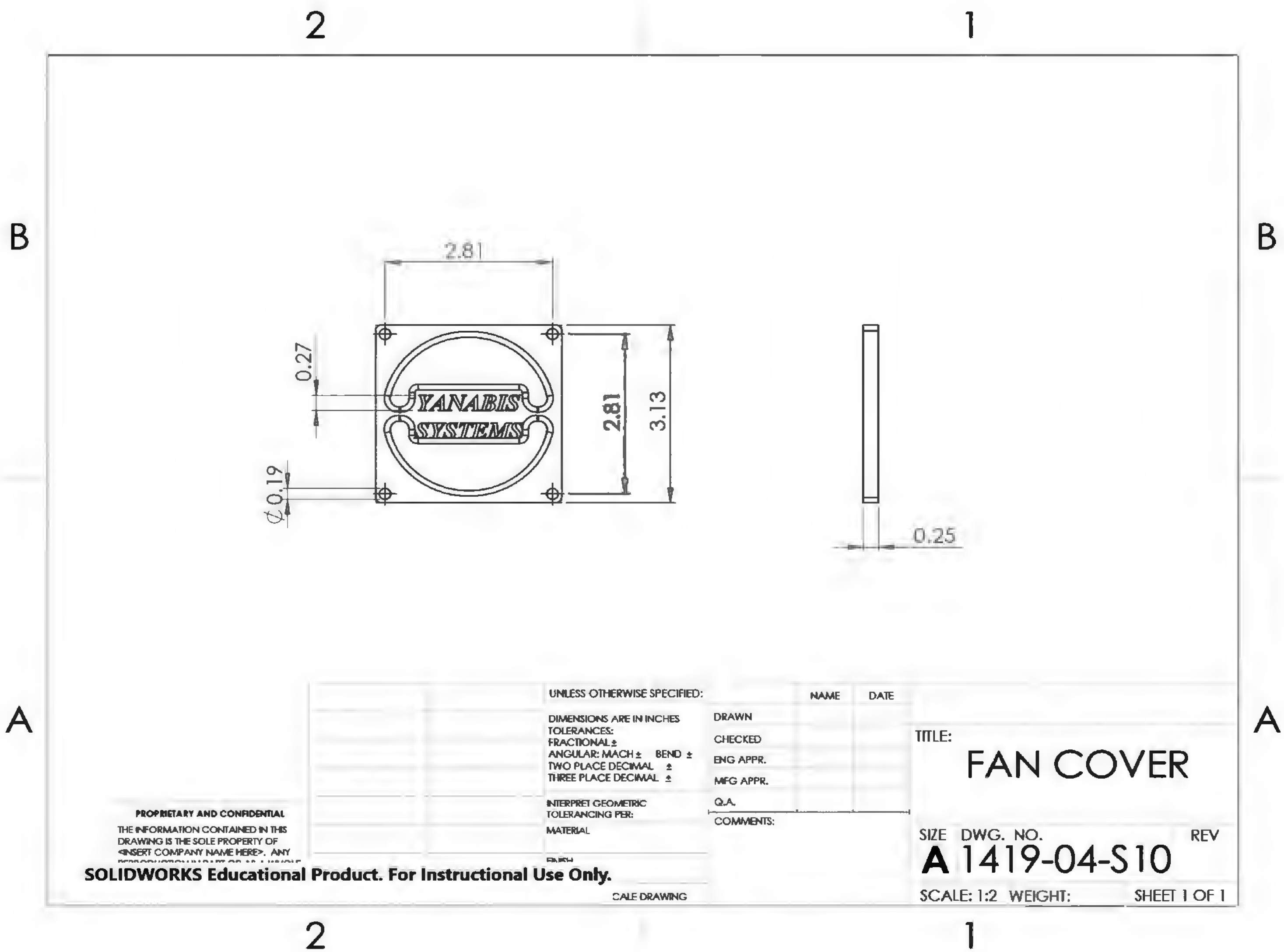


Figure C.15: Fan Cover

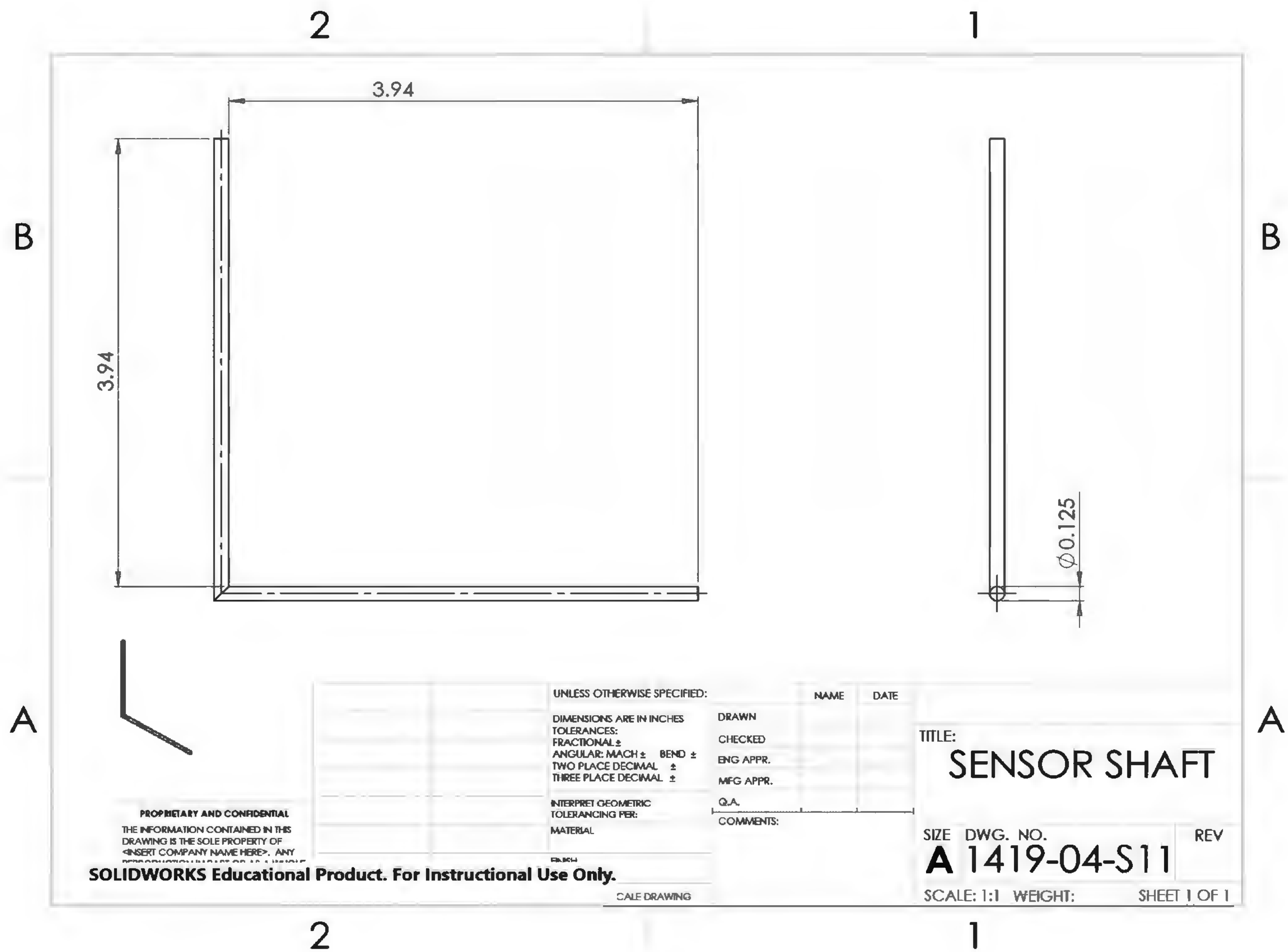


Figure C.16: Sensor Shaft

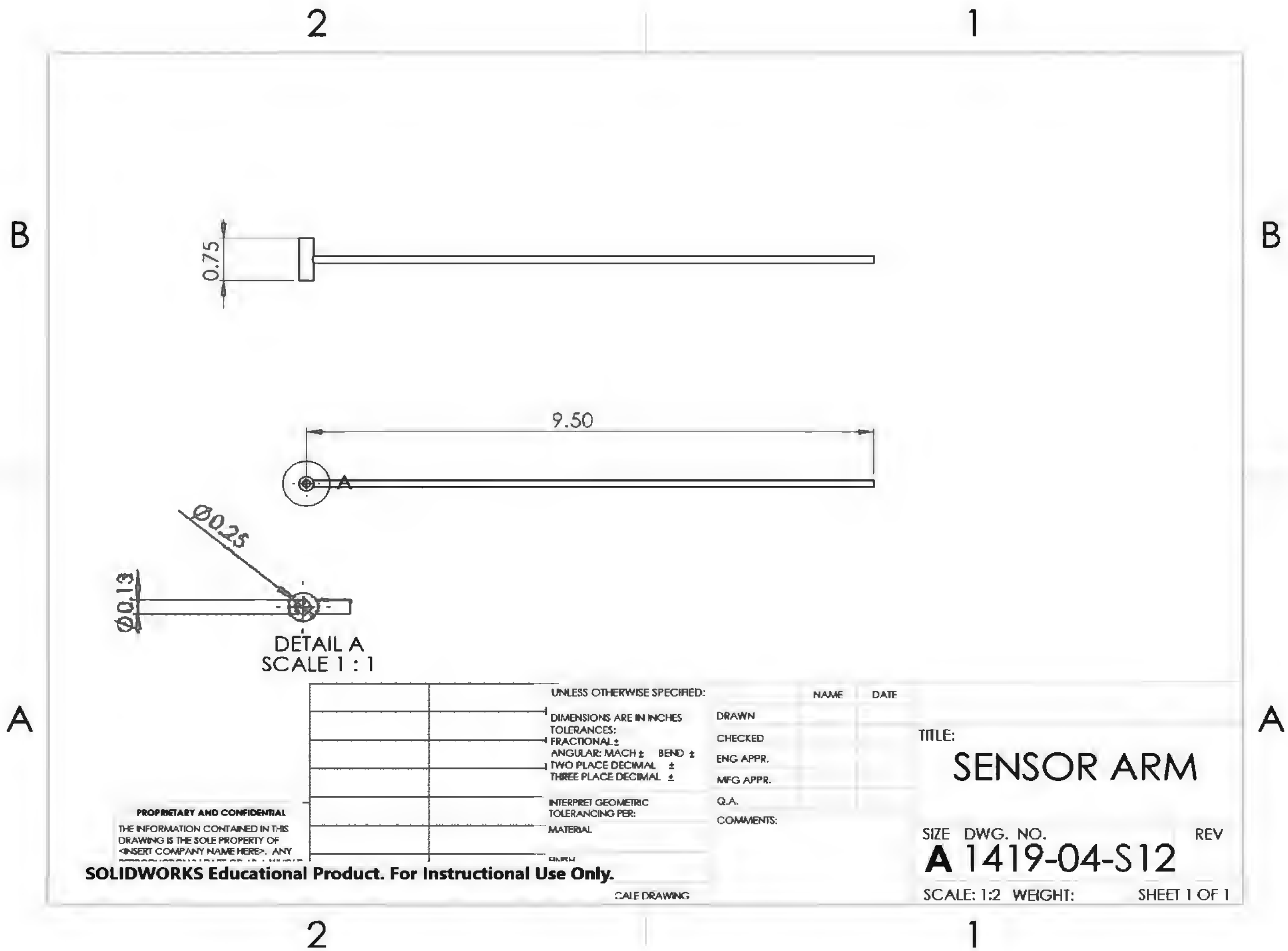


Figure C.17: Sensor Arm

D. Circuit Diagram

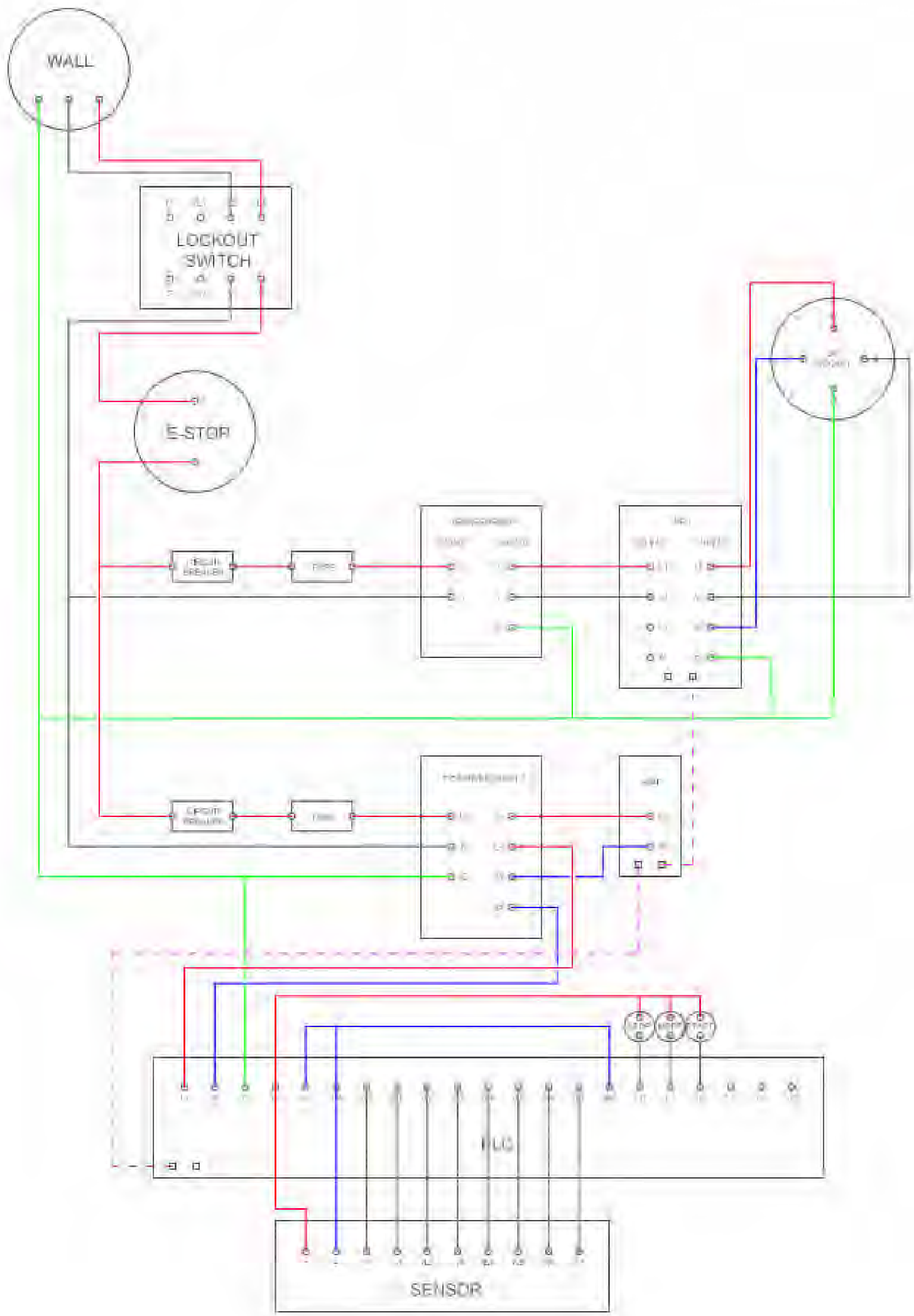


Figure D.1: Circuit diagram

E. Instruction Manual

PLC Program Instruction Manual

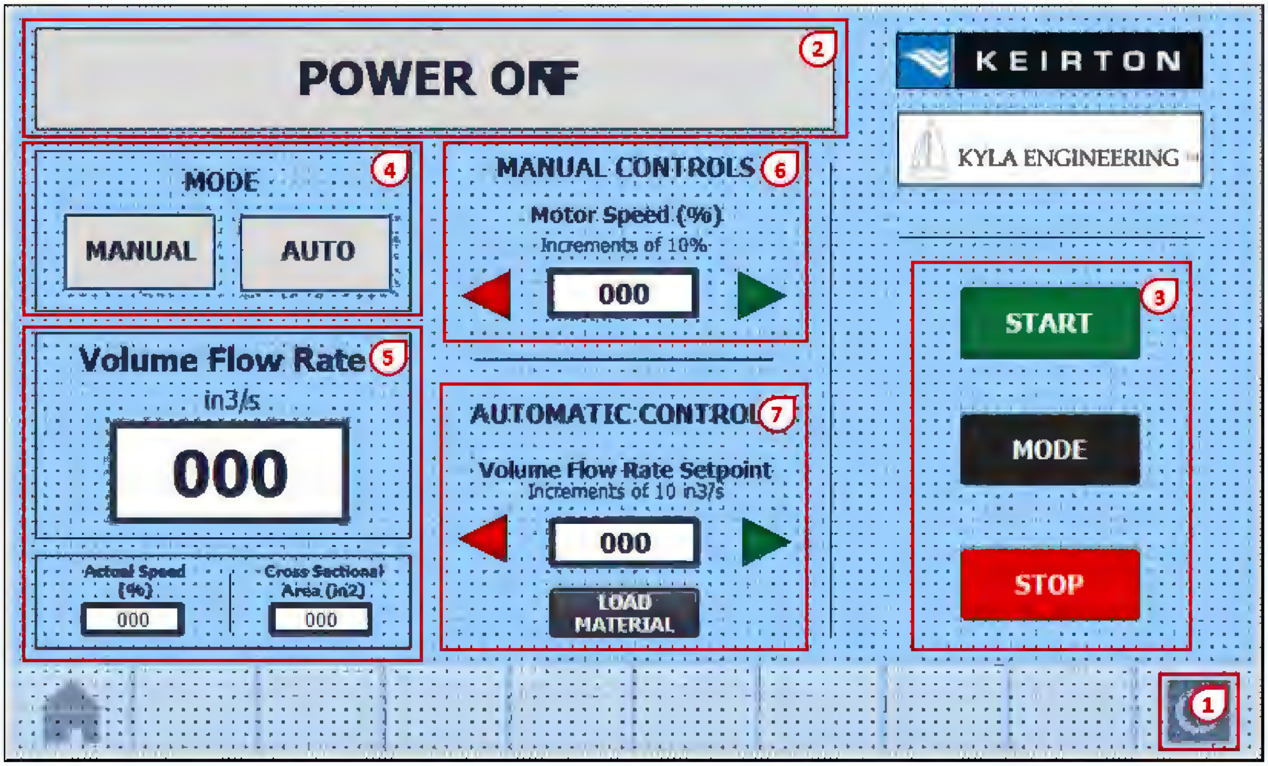


Figure D.2: The display screen of the program.

1	Exit Button	5	Information Display
2	Power Status	6	Manual Controls
3	Digital Buttons	7	Automatic Controls
4	Mode Status		

Figure D.3: Legend of the display screen numbering.

1. Exit Button

This button exits the program and returns the screen to the HMI home screen.

2. Power Status

This displays the current power state of the program. Manual/automatic controls are enabled when the power state is ON (green) and disabled when the power state is OFF (red).

3. Digital Buttons

The START digital button switches the power state to ON. The STOP digital button switches the power state to OFF. The current power state can be viewed from the Power Status element. The MODE digital button toggles the mode between MANUAL and AUTO. When the program is first started, the mode will be set to manual by default. The current mode can be viewed from the Mode Status element. Physical buttons on the control box serve the same functionality and can be used in lieu of the digital buttons.

4. Mode Status

This displays the current mode of the program. The mode can be either MANUAL or AUTO. Manual controls are enabled when the mode is set to MANUAL. Automatic controls are enabled when the mode is set to AUTO.

5. Information Display

This section displays relevant information to the program's operation. The top element displays the measured volume flow rate through the sensor in cubic inches per second. The bottom left element displays the actual speed of the conveyor in percentage (0 - 100%). The bottom right element displays the measured cross sectional area through the sensor in square inches.

6. Manual Controls

Displays the conveyor speed setpoint. Pressing the green arrow will increment the setpoint by 10% and pressing the red button will decrement the setpoint by 10%. The actual conveyor speed can be seen on the information display.

7. Automatic Controls

Displays the volume flow rate setpoint. The speed of the conveyor will be automatically controlled by the program to achieve the setpoint. Pressing the green arrow will increment the setpoint by 10% and pressing the red button will decrement the setpoint by 10%. The measured volume flow rate can be seen on the information display. For safety concerns, when no material is detected on the conveyor, the conveyor will not move. The LOAD MATERIAL button is used when loading material onto an empty conveyor. Holding down the LOAD MATERIAL button will override the automatic control and set the conveyor speed at 20%. When released, the LOAD MATERIAL button will return to automatic control of the conveyor speed.

F. Other related material

F.1 Height – cross-sectional area relationship calculation

ADC Quantized result:

ADC quantized result of the voltage reading from the potentiometer

Equation 1

$$quantized\ result = round\left(\frac{input - ref}{resolution}\right)$$

Equation 2

$$quantized\ result = round\left(\frac{input - ref_{low}}{ref_{high} - ref_{low}}\right)(2^n - 1)$$

The input is the voltage reading from the potentiometer, ref_{high} is the supply voltage which is 3.3 volts, ref_{low} is the neutral wire which is 0 volts, and n is the resolution of the MSP430 which is 12 bits.

From the equation, the result can vary from 0 to 4095.

ADC result to cross-sectional area:

Once the sensor has been mounted, the lowest and highest height reading is used to calibrate the code. The lowest reading corresponds a zero height reading, and the highest reading correspond to the total height of the conveyor, which is 3.50 inches from figure 17. Linear interpolation is then used to find the actual height from the ADC result.

Height [inches]	ADC reading
0	Reading at h=0, h_{min}
Calculated height, h	ADC sample result
3.50	Reading at h=3.50, h_{max}

Figure F.1: ADC Reading

Linear interpolation yields the following equation:

Equation 3

$$h = \frac{h_{min} - result}{h_{min} - h_{max}} * 3.50$$

G. Design review package

Conveyor Automation and Control System

1819-4

Critical Design Review Package

L. Burgos | K. Manson | S. Yu |

January 30, 2019

Product Development Specification (PDS)

Product development has been based on meeting the technical requirements outlined in the RFP. The design of the mounting mechanisms uses the same bracket material on the conveyor and takes advantages of fasteners already used on the assembly. This assures that all materials used are pharmaceutical grade and require little modification to the conveyor.

A control system was designed to power the conveyor motor and used Keirton specified electrical components. This was specified in the RFP and confirmed in the proposal presented by the team.

The project objective of measuring the volume flow rate on the conveyor is being met with the laser scanner mechanism as well as the evener mechanism. The project is broken down into three main categories: electrical, mechanical, and software. With electrical work 90% done (control panel), mechanical design has started as well as software design. Further details about product design and development can be found under engineering data and schematics.

Engineering Data

Fig. 1 shows the conveyor assembly that will be used for the project. Approximate size is 5 ft long, with a belt that's 4 inches wide. The cross-section measures approximately 16 in^2.

Figure G.1 - Conveyor assembly drawing

Figure G.2 - Conveyor motor and gearhead

The motor used for the conveyor is shown in figure 2. It is an induction motor and requires 240VAC 3 phase. Configuration of the gearhead is outside the project scope.

Motor Control

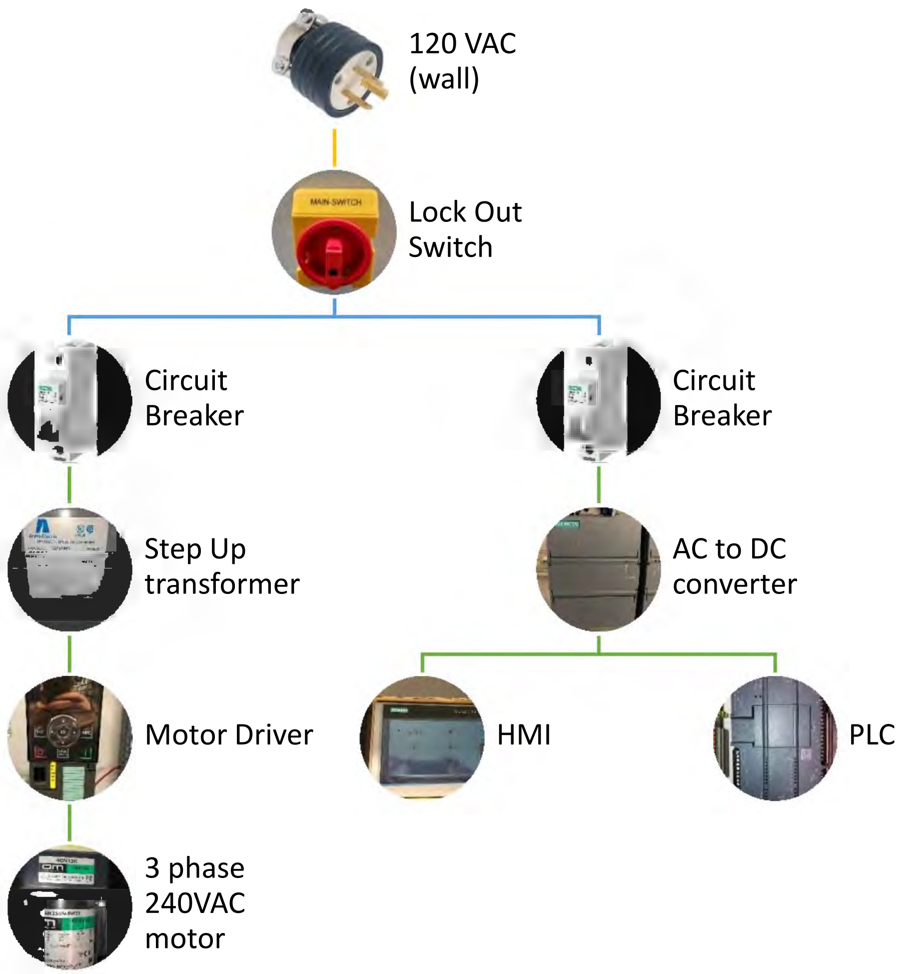


Figure G.3 - Power flow chart

The power circuit is composed of components required by Keirton – Siemens components such as motor driver, AC to DC converter, HMI and PLC. The team specified a circuit breaker and transformer to complete the power flow chart.

To power the motor, the wall voltage is increased to 240 using a transformer. The driver then converts this to 3 phase 240VAC. The driver, which will also eventually receive instruction from the PLC, powers the motor.

Both the HMI and the PLC requires 24VDC. This comes from the AC to DC converter, which takes in 120 VAC and outputs 24 VDC. The PLC will be used to run the software program developed to implement volume feed rate control. The HMI will allow user to provide inputs and save recipes as the project requirement outlined.

Mounting Mechanism

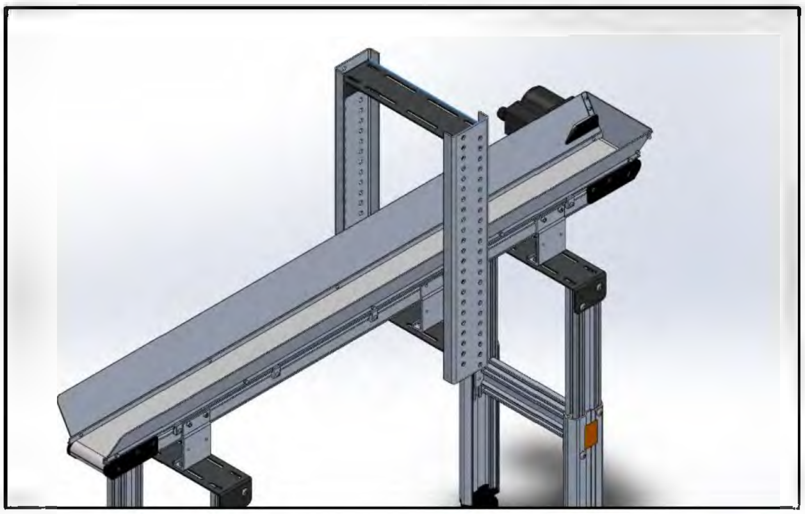


Figure G.4 - Mounting bracket

The mounting bracket is designed to hold a laser scanner or the evener mechanism. If time permits to prototype the evener mechanism, two of these brackets will be built. One will hold the laser scanner and the other for the evener mechanism. A clear protective case is also proposed to reduce noise in the data.

The bracket bolts on to the conveyor stand without requiring any modification. It also uses the bolts already used in the conveyor legs. This allows the bracket to be mounted to conveyors already in service in the field. With this design, the bracket with the scanners and the control panel can be sold as an independent unit to customers.

Program Flow Chart

Software program main goals:

- Display Q (volume flow rate) on HMI
- Toggle between controlled (user defined) and uncontrolled (default) Q

Identified I/O

- User inputs
  - HMI
  - Buttons
    - Red (stop)
    - Black (toggle)
    - Green (start)
- Sensors
  - Laser scanner
  - Evener
- Actuator
  - VFD/Motor

- Safety
    - E-Stop
    - Lockout Switch

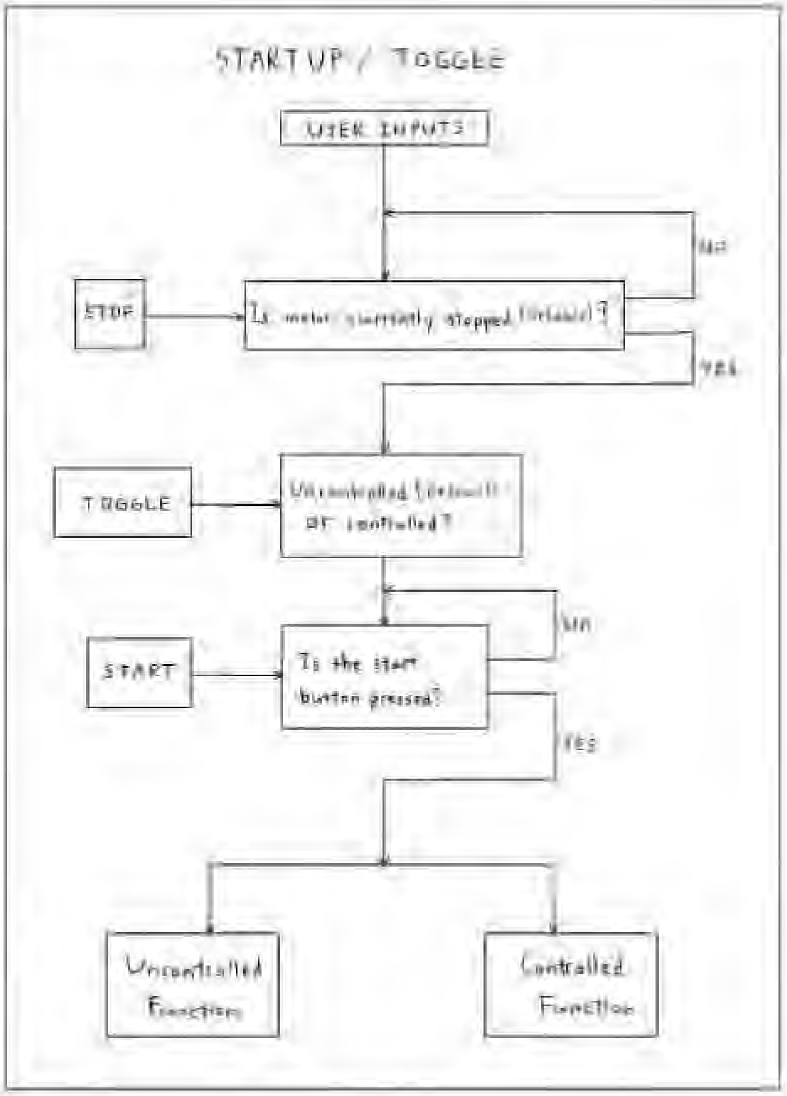


Figure G.5 - Top level start-up function

Figure 5 shows the first version of the start-up program. It will ask the user for the mode they want: uncontrolled or controlled. Uncontrolled mode will allow to user to change the conveyor speed at any point during run time to achieve their desired volume flow rate. The volume flor rate will be displayed on the screen.

Controlled function asks the user for a desired volume flow rate and adjusts the conveyor speed accordingly to achieve this. Safety functions will be implemented such as slowing down or stopping the motor when volume flow rate being read is zero for a given amount of time.

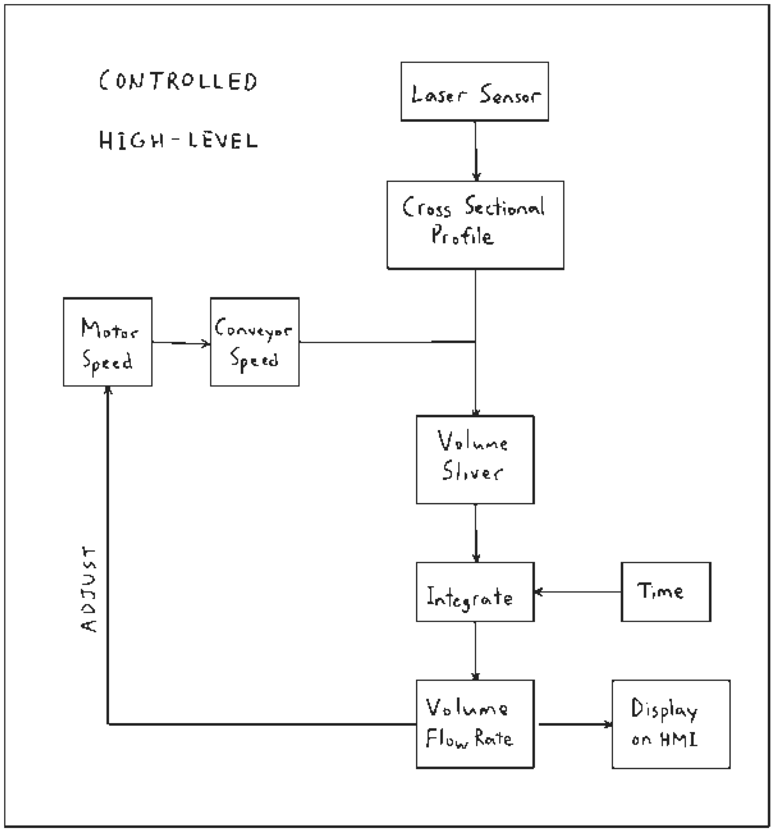


Figure G.6 - Proposed 'controlled' function

Figure 6 shows the controlled mode. These functions, fig 10 and 11, will be written in more detail once the PLC has been configured.

PLC uses ladder logic. However, function blocks used within this ladder logic can be made and coded using C. The team will further investigate these functions in the next weeks.

Competitive analysis for existing product

As there are currently no companies that offers volume flow rate control for cannabis production and processing, no competitive analysis can be performed. However, to make sure the project meets all objectives and requirements, Keirton engineering representative is kept up to date on the project status and progress.

Drawings and Schematics

The next figures show technical schematics of the project.

Circuit Diagram

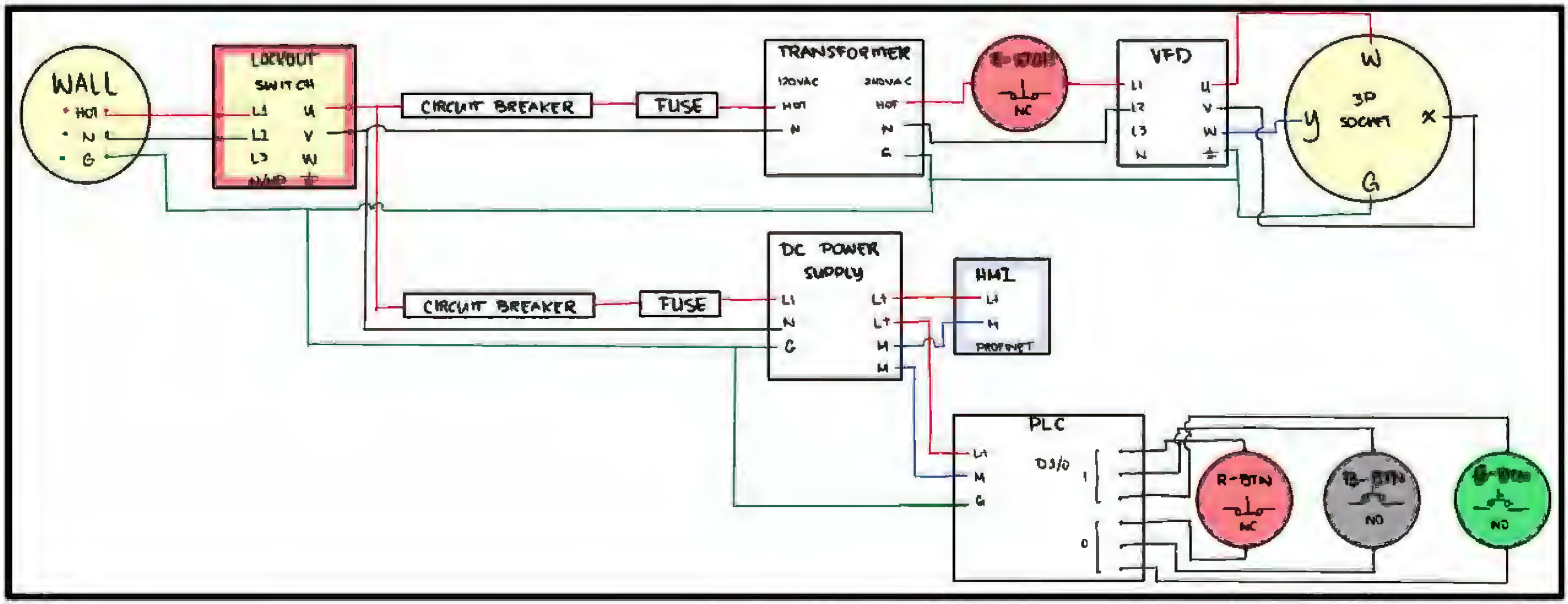


Figure G.7 - Power circuit diagram

The figure above shows the schematic of the power circuit. The control panel is only currently wired to provide power to all components.   Once the PLC is powered up, the team can configure and download code to it. Further wiring will be done to allow communication between the PLC, HMI, and the driver (VFD).

Control panel

The following pictures show how components are mounted on the control panel. The HMI and buttons are placed on the left side to accommodate the driver inside the control box. An instruction manual will be posted on the right-hand side of the HMI.

Figure G.8 - Control panel externally mounted parts

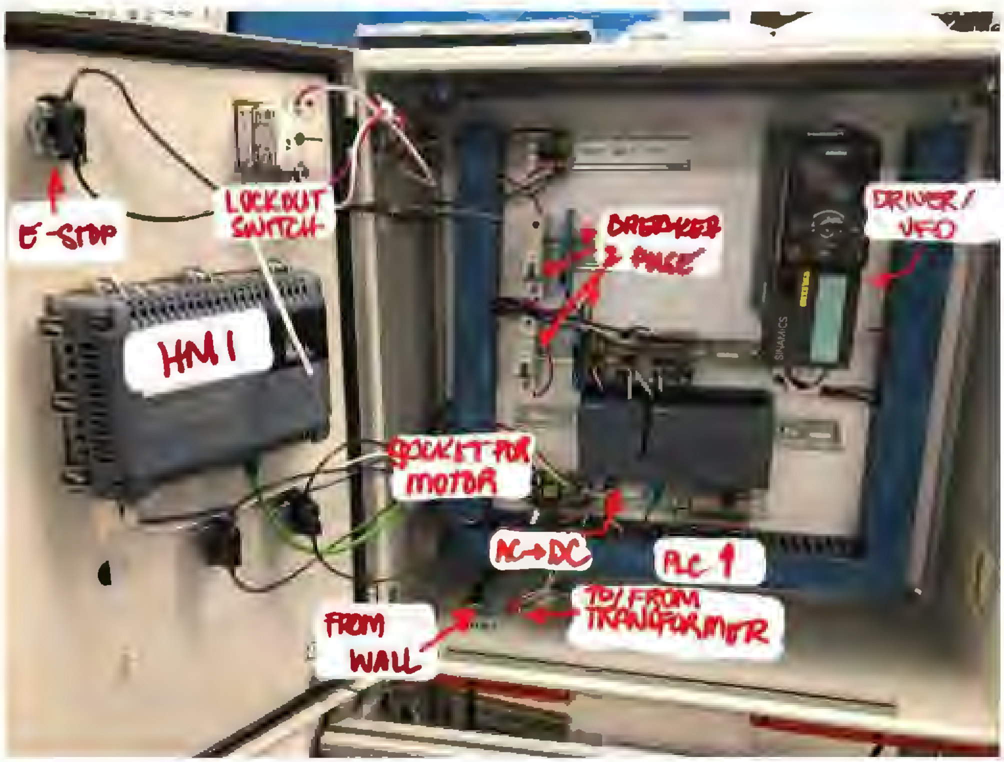


Figure G.9 - Control panel internally mounted components

Heat sensitive components such as the PLC are placed near the bottom to minimize exposure to heat produced during runtime. Each circuit breaker is placed on the far left, to mark the start of components powered in series. This strategy helps during troubleshooting.

Stand

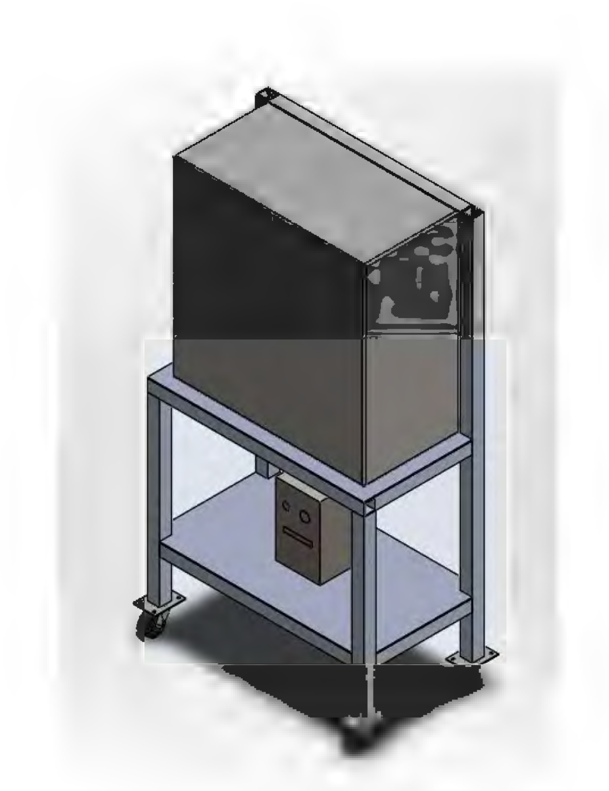


Figure G.10 - Control panel stand

The team designed and built the stand for the control panel. The transformer sits on the lower level of the stand. Since the control panel has a socket for a conveyor to be plugged in, it can be brought to a site for testing, instead of it being hardwired to a single conveyor motor.

Schedule status and projections

Based on the current work done on the project, the project is still on schedule. The following table summarizes the project schedule as of January 2019.

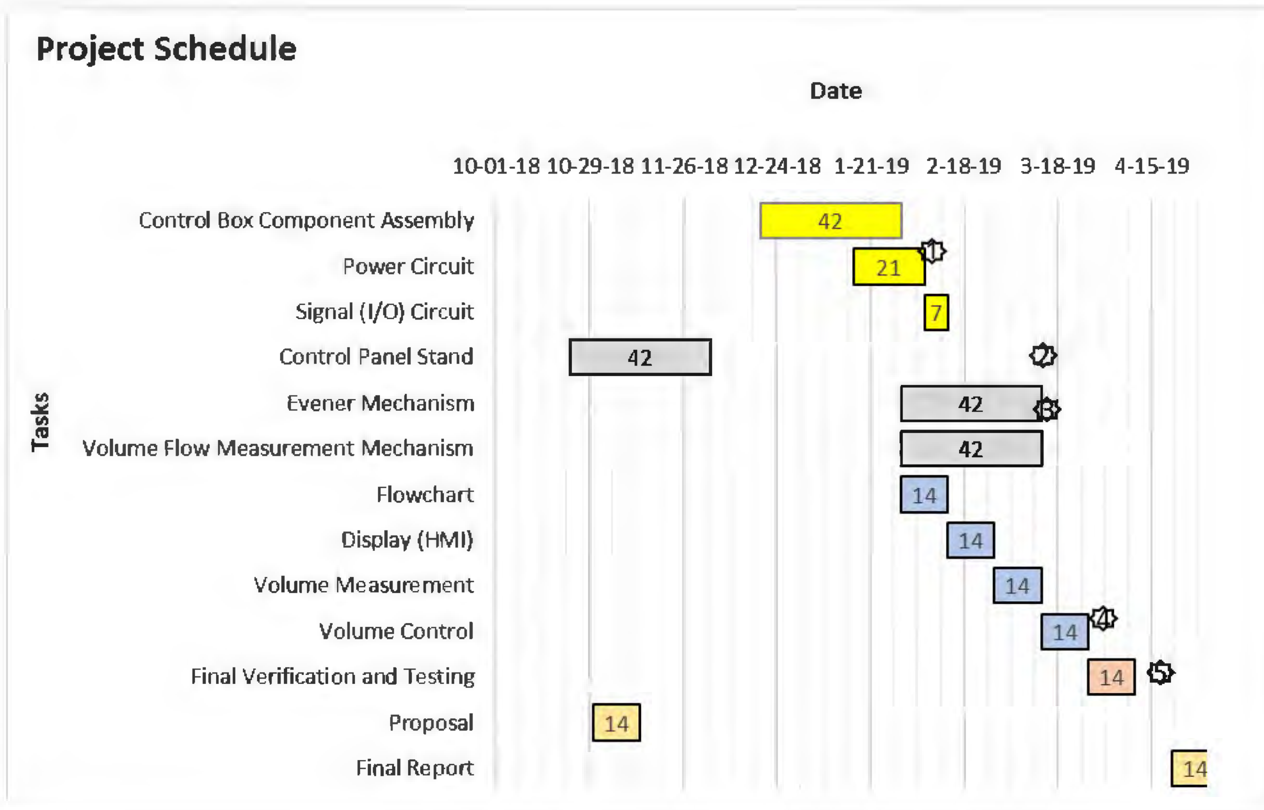


Figure G.11: Project schedule

Project risk analysis

Current risks on the project are the lead time on the laser scanner, the prototyping of the evener mechanism, and software bugs. The selection of the laser scanner may be limited by the availability of these scanners and the accompanying lead times.

Although design of the evener mechanism is well underway, the prototyping may be delayed past testing. The evener mechanism may be further pursued after the volume control has been tested and verified using the laser scanner.

The team has also allocated ample time for software design and testing. Most risk is associated with the implementation of speed control from volume flow rate reading. The risk can be best investigated during the testing phase.

Description of unusual requirements and design elements with associated high-risk

Since there has been no prior work done on the volume flow rate reading of cannabis, the use of laser scanner and integration method is the project element with the highest risk. Success cannot be determined until testing. However, the success or failure of this method will give a better insight on the nature of the product being measured.

H. Computer codes

H.1 Microcontroller C program

```
//Author: Yana Burgos
//        A00............
//        Kyle Manson
//        A00
//        Set B
//---------------------------------------------------------------------------------
//Capstone
//Ski Sensor Data Processing

//---------------------------------------------------------------------------------
//********** Header Files/ Defines **********
#include <msp430.h>  // Device specific include file
#define DELAY   1053 // Number of cycles equal to 1 ms.

//---------------------------------------------------------------------------------
//********** Function Prototypes **********
void adcInit(char);  // Initializes ADC
int adcSample(void); // Samples and returns quantized value
void msDelay(unsigned int); // Adds delay in milliseconds

//---------------------------------------------------------------------------------
//********** Main Loop **********
void main(void)
{
    WDTCTL = WDTPW | WDTHOLD;    // stop watchdog timer
    P2DIR |= BIT0; //Initialize P2.0 to be an output
    P2OUT &= ~BIT0; //Turn P2.0 off

    P3DIR |= BIT0; //Set P3.0 as output
    P3DIR |= BIT1; //Set P3.1 as output
    P3DIR |= BIT2; //Set P3.2 as output
    P3DIR |= BIT3; //Set P3.3 as output
    P3DIR |= BIT4; //Set P3.4 as output
    P3DIR |= BIT5; //Set P3.5 as output
    P3DIR |= BIT6; //Set P3.6 as output
    P3DIR |= BIT7; //Set P3.7 as output


    //Turn off the P3 ports for next use
    P3OUT &= ~BIT0;
    P3OUT &= ~BIT1;
    P3OUT &= ~BIT2;
    P3OUT &= ~BIT3;
```

```
 P3OUT &= ~BIT4;
 P3OUT &= ~BIT5;
 P3OUT &= ~BIT6;
 P3OUT &= ~BIT7;

// declare variables
 volatile int result;
 char channel = 3;   // use ADC channel 3
 volatile int in_max;    // max ADC reading
 volatile int in_min;    // min ADC reading
 volatile double h;      // material height, [in]
 volatile double Xarea;  // conveyor cross-sectional area
 volatile int aBit;      // Xarea in bits (0-255)
 volatile double hmax;   // Maximum hight of the conveyor
 volatile double amax;   // Maximum area of the conveyor
 volatile int tempstore; // temporary number
 volatile int max_var;   // Maximum variance in measurement allowed
 volatile int var;       // |current result - last result|
 unsigned int ms;        // delay in milliseconds

 //Pass in the channel that is being read to initialize it
 adcInit(channel);

 // initialize variables
 ms = 100;       // set delay to 100 ms
 max_var = 10;   // allow 10 unit variance from last result
                 // before rewriting result
                 // minimizes noise
 in_max = 3600;  // calibrated max reading
 in_min = 1900;  // calibrated min reading
 hmax = 3.626;   // conveyor max depth
 amax = 19.266;  // conveyor max cross-sectional area
 result = 0;
 //While loop to continuously poll the result of the input
 while(1)
 {
     tempstore = result;   // Store the last result for temporary use
     result = adcSample(); // Obtains the quantized value

     // minimize noise
     var = tempstore - result;   // variance of current result to last result
     if (var<0) var *=-1;        // take absolute value
     // variance is <= +/- 10, keep last result
     if (var<max_var) result = tempstore;
```

```
        // filtering section
        if (result == 28) result = tempstore;

        // make sure result is within calibrated range
        if (result<in_min) result = in_min;
        if (result>in_max) result = in_max;

        // convert ADC result to cross sectional area
        h= (((in_min-result)*hmax)/(in_min-in_max));
        if (h<0.1) h=0.0;

        Xarea = (0.4653*h*h) + (3.625*h); // area in in^2
        Xarea = Xarea*255/amax;           // area in bits
        aBit = Xarea; // convert to int

        P3OUT = aBit; // output to PLC
        msDelay(ms);  // 100 ms delay until next loop
    }
}

//------------------------------------------------------------------------------
// Description:  Initialize ADC
// Arguments:    channel - ADC channel
// Return value: none
void adcInit(char channel)
{
    ADC12CTL0 &= ~ADC12ENC; //Ensures enable conversion bit is cleared for
config.
    ADC12CTL0 = ADC12ON; //4 cycle sample time, turn on ADC
    ADC12CTL1 = ADC12SHP | ADC12SSEL_3; //Uses sampling timer with SMCLK, output
to MEM0

    P6SEL|= channel; //Use P6.channel as an analog input
    ADC12MCTL0 = channel;
}

//------------------------------------------------------------------------------
// Description:  Take ADC sample
// Arguments:    none
// Return value: result - conversion result
int adcSample(void)
{
    volatile int result; //Variable to hold the result

    ADC12CTL0 |= ADC12ENC | ADC12SC; //Start conversion
```

```
    P2OUT |= BIT0; //Turn P2.0 High
    while((ADC12IFG & ADC12IFG0)== 0){ } //Wait for the coversion to complete
(13+4 cycles)
    result = ADC12MEM0; //Retrieve the conversion result
    P2OUT &= ~BIT0; //Toggles P2.0 Low

    return result; //Returns the result
}

//-----------------------------------------------------------------------------
// Description:  create time delay betweeen steps
// Arguments:    ms - desired delay in milliseconds
// Return value: none
void msDelay(unsigned int ms)
{
    while (ms > 0)
    {
         //Delay 1 ms.
        _delay_cycles(DELAY);
        ms--;
    }
}
```

H.2 PLC Ladder Logic Code

PLC Tag Table

Start Button	Bool	%I1.2	Start button signal.
Stop Button	Bool	%I1.0	Stop button signal.
Power Coil	Bool	%M0.0	Power coil (ON/OFF).
Toggle Button	Bool	%I1.1	Toggle button signal.
Toggle Edge Bit	Bool	%M1.0	Intermediary variable.
Toggle Edge Coil	Bool	%M1.1	Intermediary variable.
Toggle Coil	Bool	%M1.2	Use this to find state of toggle. '0' is manu...
VFD Control Word	Word	%QW256	16#047E -> 16#047F to turn on VFD.
VFD Setpoint	Int	%QW258	0000 -> 16380 for 0% -> 100% (0.625 ft/s...
VFD Status	Word	%IW256	Valid number means its interfacing ok.
VFD Actual Speed	Int	%IW258	0000 -> 16380 for 0% -> 100% (0.625 ft/s...
Dummy Variable 0	Bool	%Q0.0	Stores unused edge bit data.
Increment Speed Button	Bool	%M2.0	Increment speed button signal.
Decrement Speed Button	Bool	%M3.0	Decrement speed button signal.
Increment Speed Edge Bit	Bool	%M2.1	Unused. '1' on negative edge. '0' otherwise
Decrement Speed Edge Bit	Bool	%M3.1	Unused. '1' on negative edge. '0' otherwise
VFD Setpoint Percent Display	Int	%MW4	VFD setpoint value displayed in percentag...
VFD Setpoint Normalized	Real	%MD6	Intermediary variable.
VFD Actual Speed Percent Displ...	Int	%MW10	VFD actual speed value displayed in perce...
VFD Actual Speed Normalized	Real	%MD12	Intermediary variable.
Dummy Variable 1	Bool	%Q0.1	Stores unused edge bit data.
Volume Flow Rate Measurement	Int	%MW16	Volume flow rate measurement (cfm).
Motor Speed Difference	Int	%MW18	Difference between motor setpoint and ac...
Speed Overload	Bool	%M20.0	Turns on/off to keep the setpoint/actual sp...
Cross Sectional Area	Byte	%IB0	Cross sectional area input from sensor (un...
Volume Flow Rate Setpoint in I...	Int	%MW25	The desired volume flow rate setpoint in3/s
Increment Volume Flow Setpoi...	Bool	%M30.0	Increment volume flow setpoint button si...
Decrement Volume Flow Setpo...	Bool	%M30.1	Decrement volume flow setpoint button si...
Increment Volume Flow Setpoi...	Bool	%M30.2	Unused. '1' on negative edge. '0' otherwise
Decrement Volume Flow Setpo...	Bool	%M30.3	Unused. '1' on negative edge. '0' otherwise
Start Digital Button	Bool	%M40.0	Start button on HMI.
Stop Digital Button	Bool	%M40.1	Stop button on HMI.
Toggle Digital Button	Bool	%M40.2	Toggle button on HMI.
Toggle Digital Edge Bit	Bool	%M40.3	Intermediary variable.
Cross Sectional Area Display	Int	%MW42	Measured cross sectional area displayed o...
Load Material Button	Bool	%M41.0	Digital button to force conveyor moveme...
Load Material Edge Bit 1	Bool	%M41.1	Intermediary variable.
Load Material Edge Bit 2	Bool	%M41.2	Intermediary variable.
Load Material Coil	Bool	%M41.3	Force conveyor movement during autom...
Load Material Release	Bool	%M41.4	Bit to signal when the load material butto...
Dummy Variable 2	Bool	%Q0.2	Stores unused edge bit data.

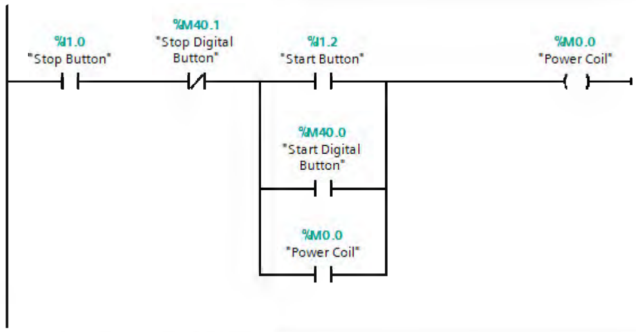
Main Block

▼ **Block title:** "Main Program Sweep (Cycle)"

Comment

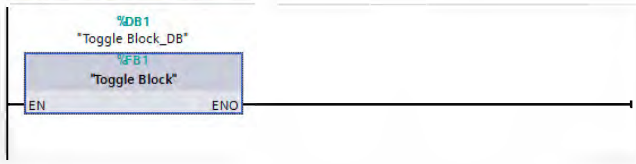
▼ **Network 1:** Start-up Circuit

Latch on start-up circuit.



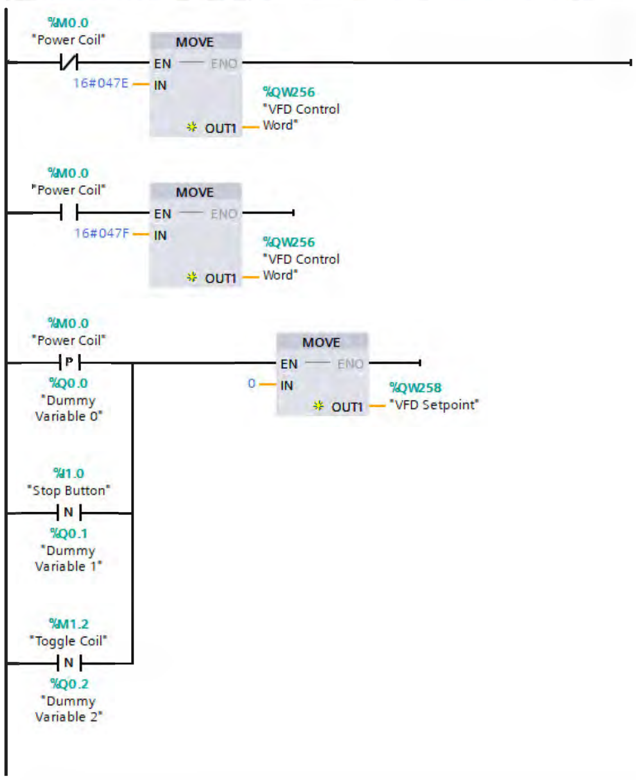
▼ **Network 2:** Toggle button circuit.

Toggle button turns a coil on/off.



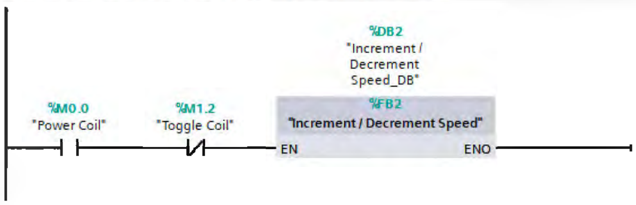
▼ **Network 3:** VFD startup.

Stop button to stop VFD and reset speed. Start button to start VFD (starting speed set at rest).



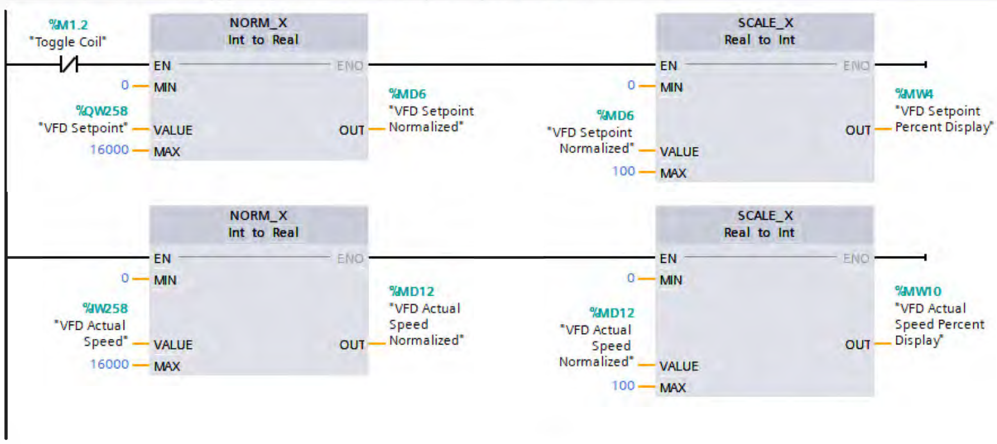
Network 4: Increment / decrement circuit (manual control).

Function controlled via HMI. Runs in manual mode when power is on.



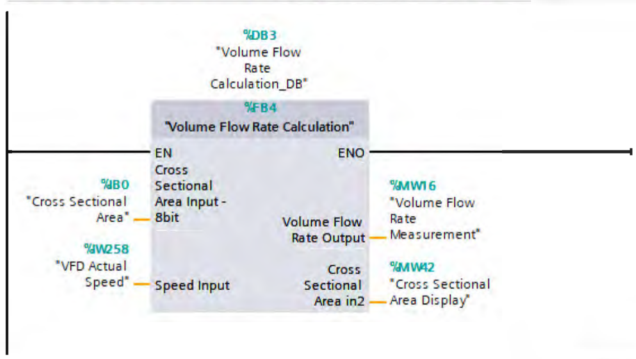
Network 5: Display VFD setpoint in HMI (in percentage).

Convert 0-16000 to 0-100%. Always running in manual mode for setpoint. Always running for actual speed.



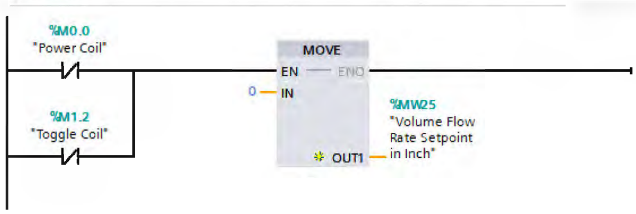
Network 6: Volume flow rate calculation.

Scales (adds units) area and speed input, then calculates volume flow rate in cfm.



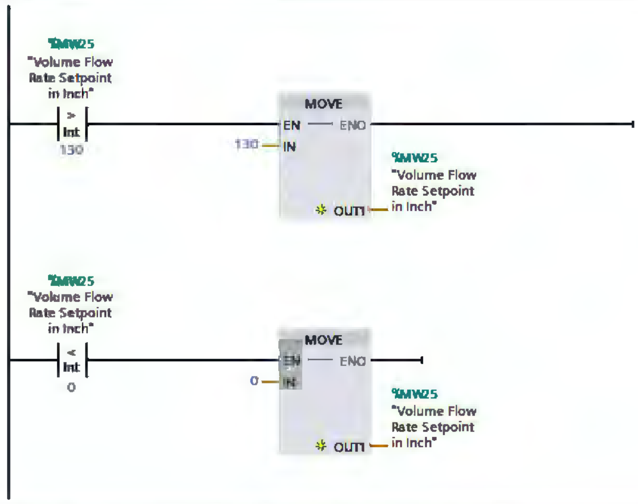
Network 7: Resets the volume flow rate setpoint when power is off or in manual mode

Comment



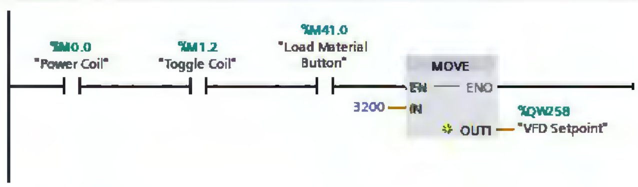
Network 8: Caps the setpoint within 0 to 130 in/s.

Comment



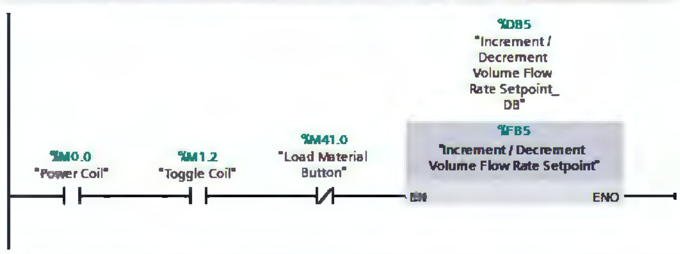
Network 9: Force conveyor movement during automatic mode (ON/OFF).

Comment



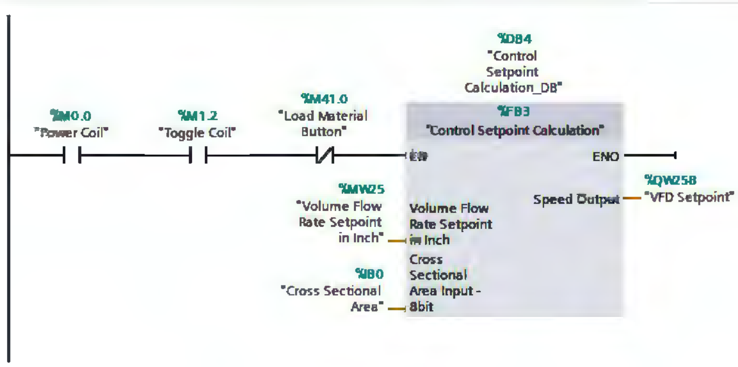
Network 10: Increment / decrement circuit (automatic control).

Function controlled via HMI. Runs in automatic mode when power is on.



Network 11: VFD setpoint calculation.

Scale the area input (adds units) and uses it with the volume flow rate setpoint to find the VFD setpoint.

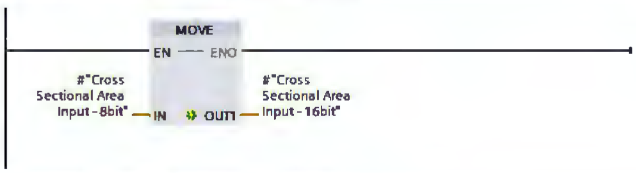


Control Setpoint Calculation Block

▼ Input								
Volume Flow Rate Set...	Int	0	Non-ret...	☑	☑	☑	☐	The desired volume flow rate (in3/s).
Cross Sectional Area I...	Byte	16#0	Non-retain	☑	☑	☑	☐	Cross sectional area measurement from
▼ Output								
Speed Output	Int	0	Non-retain	☑	☑	☑	☐	Speed setpoint to VFD (no units).
▼ InOut								
<Add new>								
▼ Static								
<Add new>								
▼ Temp								
Cross Sectional Area I...	UInt			☐	☐	☐	☐	Cleaned up cross sectional input. 0 to 2...
Normalized Cross Sect...	Real			☐	☐	☐	☐	
Cross Sectional Area i...	Real			☐	☐	☐	☐	sqft.
Volume Flow Rate Set...	Real			☐	☐	☐	☐	in3/s
Speed in Imperial	Real			☐	☐	☐	☐	ft/s.
Normalized Speed	Real			☐	☐	☐	☐	
Volume Flow Rate Set...	Real			☐	☐	☐	☐	ft3/s.
▼ Constant								
Max Speed	Real	0.6		☐	☐	☐	☐	ft/s.
Max Area	Real	0.1338		☐	☐	☐	☐	sqft.

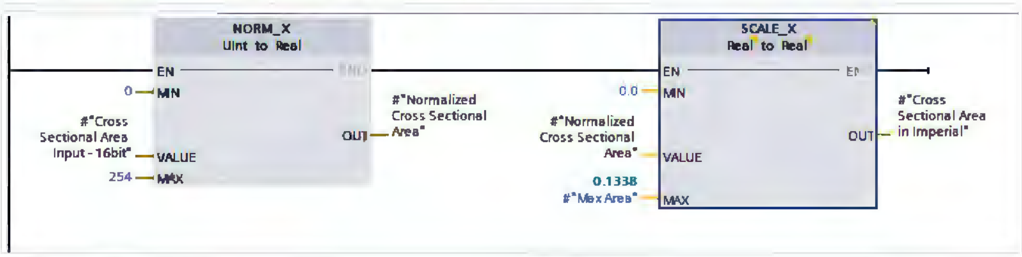
Network 1: Storing 8 bit sensor input in 16 bits.

8bit to 16bit conversion necessary for normalization.



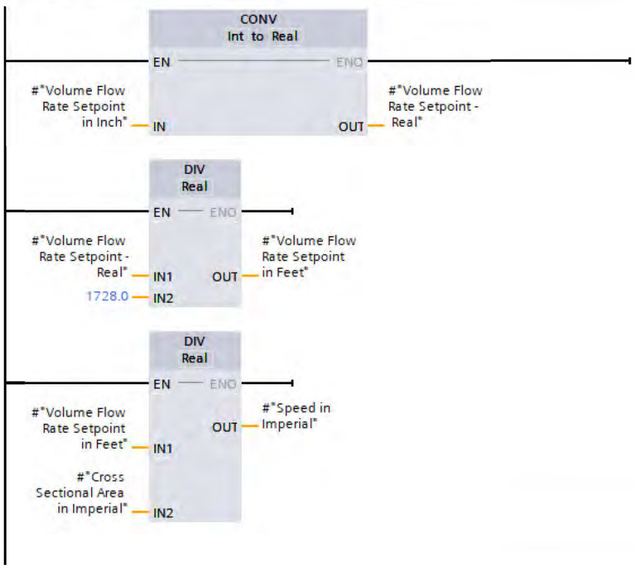
Network 2: Cross sectional area conversion to sqft.

Cross sectional area input from sensor (no units) -> Cross sectional area input from sensor (sqft).



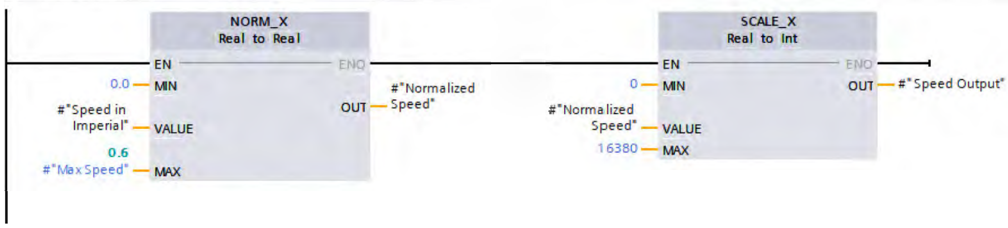
Network 3: Calculating the desired speed.

Speed in ft/s.

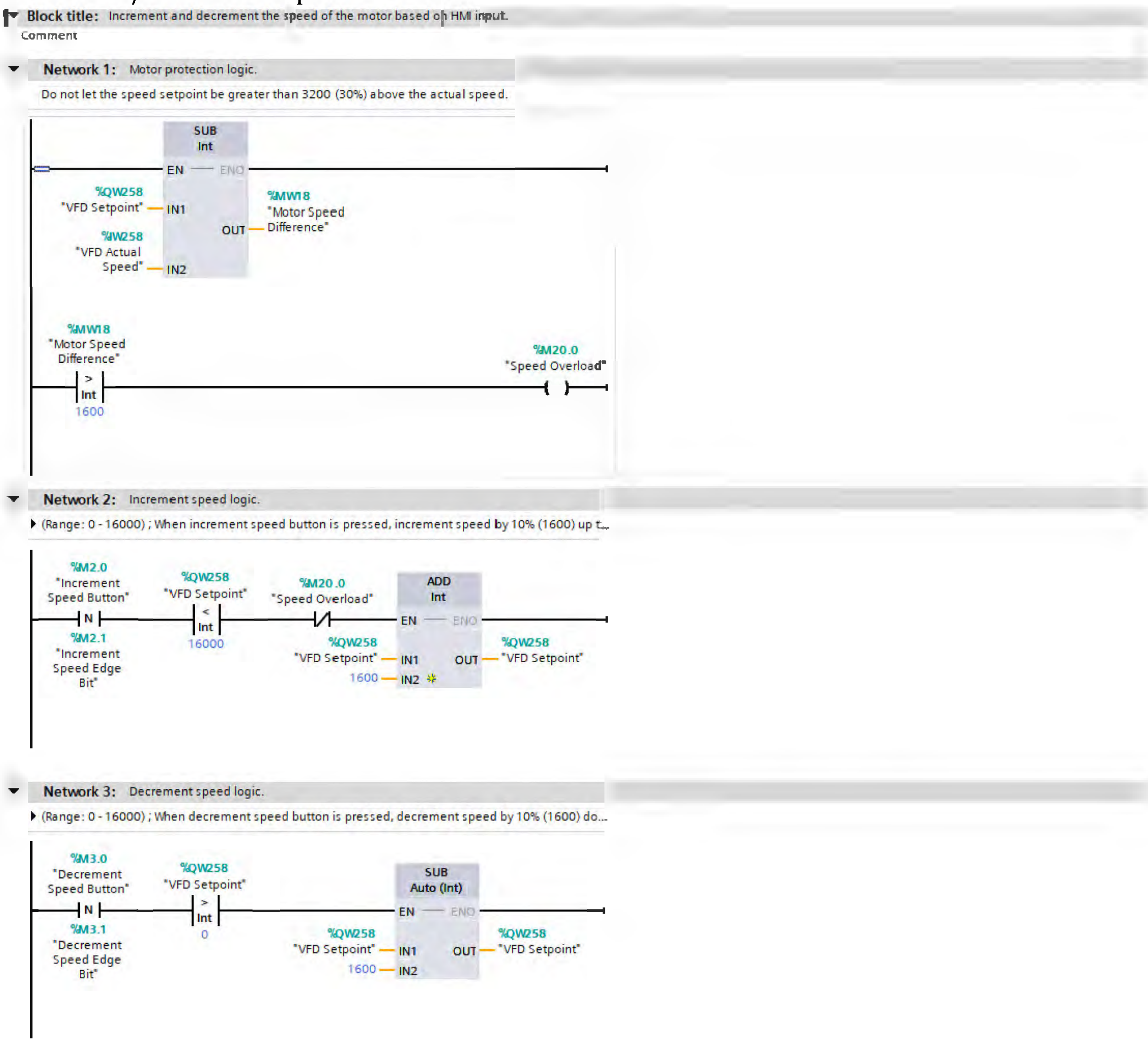


Network 4: Converting the speed output into the motor speed setpoint.

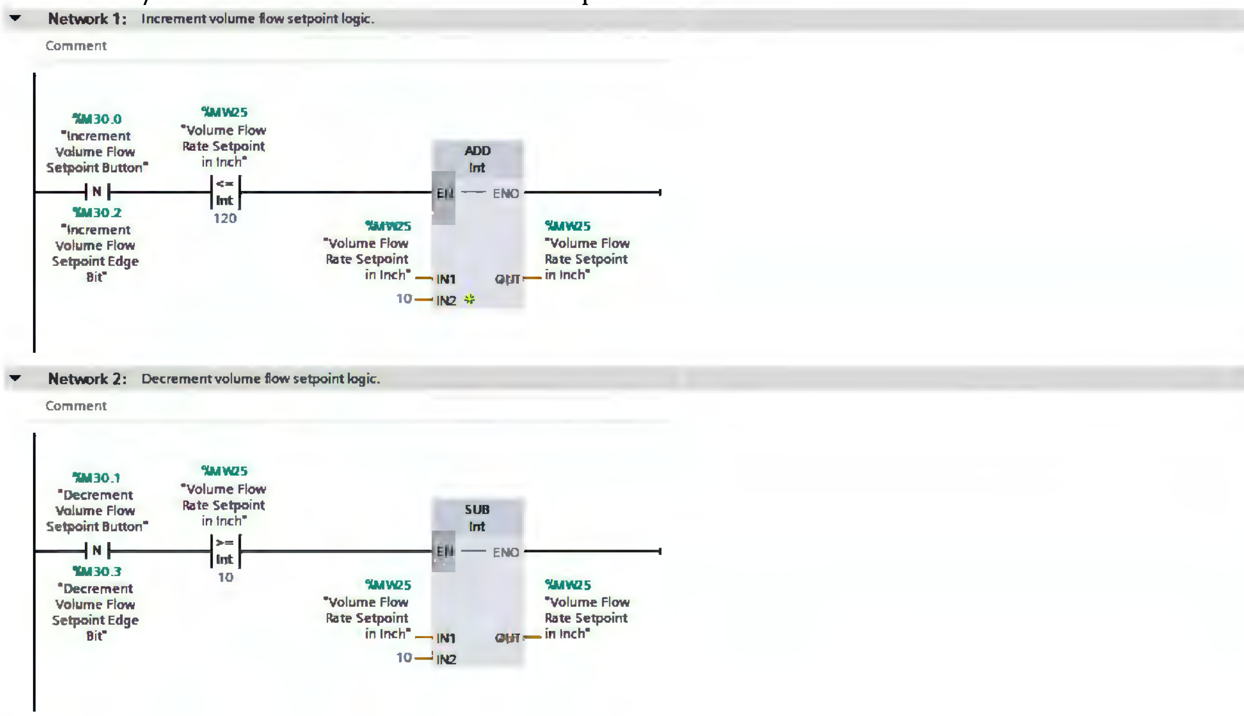
ft/s -> unitless.



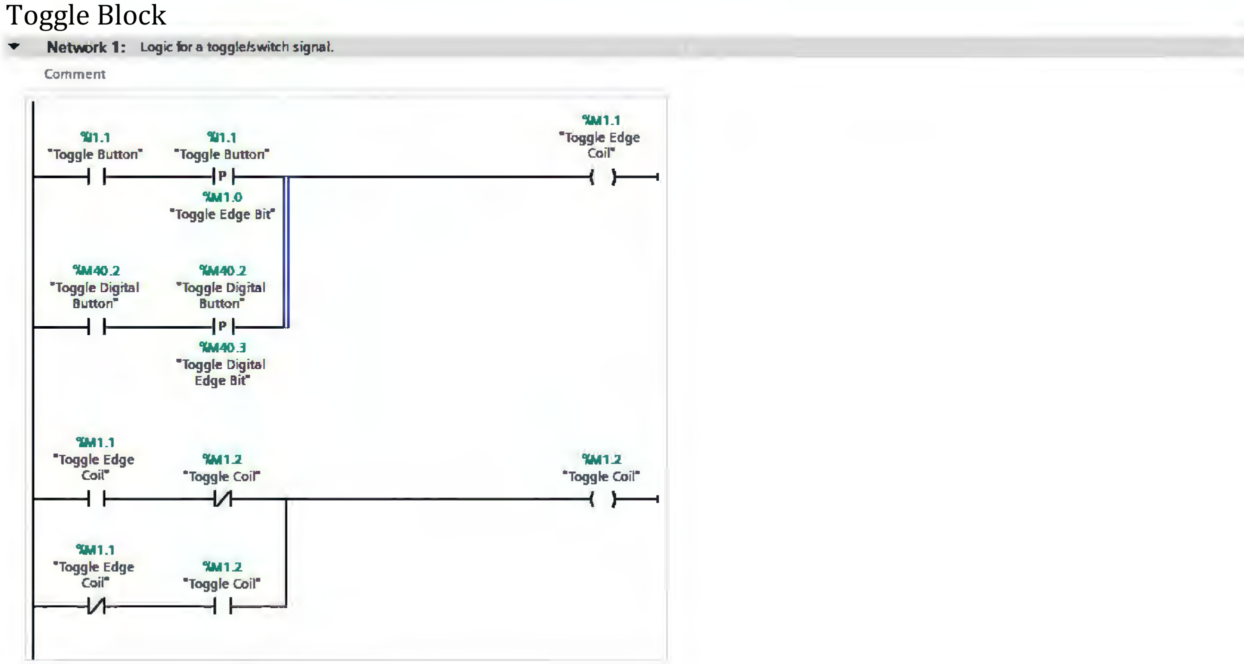
Increment / Decrement Speed Block



Increment / Decrement Volume Flow Rate Setpoint Block



Toggle Block

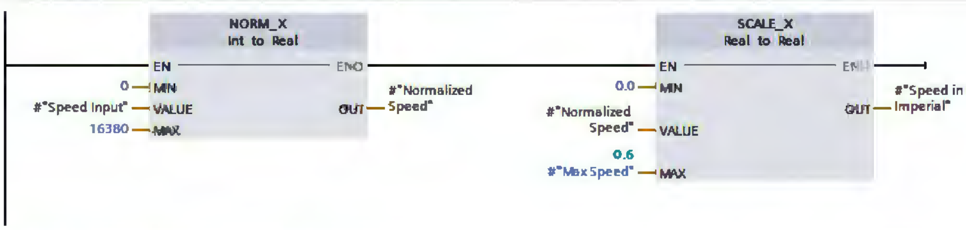


Volume Flow Rate Calculation Block

Name	Data type	Default value	Retain	Comment
Input				
Cross Sectional Area I...	Byte	16#0	Non-ret...	Cross sectional area measurement from
Speed Input	Int	0	Non-retain	Actual speed input from VFD (no units).
Output				
Volume Flow Rate Out...	Int	0	Non-retain	Volume flow rate output in cfm.
Cross Sectional Area in2	Int	0	Non-retain	The measured cross sectional area in in2
InOut				
<Add new>				
Static				
<Add new>				
Temp				
Normalized Speed	Real			
Speed in Imperial	Real			ft/s.
Volume Flow Rate in I...	Real			ft3/s.
Normalized Cross Sect...	Real			
Cross Sectional Area I...	Real			sqft.
Volume Flow Rate in F...	Real			ft3/s.
Cross Sectional Area I...	UInt			Cleaned up cross sectional input. 0 to 2...
Volume Flow Rate in I...	Real			in3/min.
Cross Sectional Area I...	Real			in2.
Constant				
Max Speed	Real	0.6		ft/s.
Max Area	Real	0.1338		sqft.

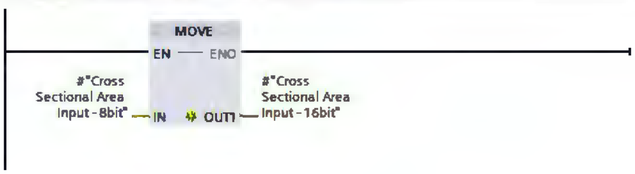
Network 1: Speed conversion to ft/s.

Actual speed input from VFD (no units) -> Actual speed input from VFD (ft/s).



Network 2: Storing 8 bit sensor input in 16 bits.

8bit to 16bit conversion necessary for normalization.

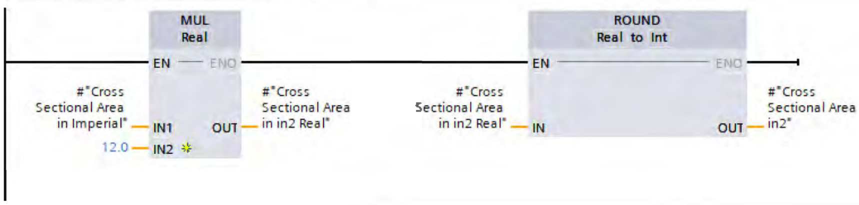


Network 3: Cross sectional area conversion to sqft.

Cross sectional area input from sensor (no units) -> Cross sectional area input from sensor (sqft).

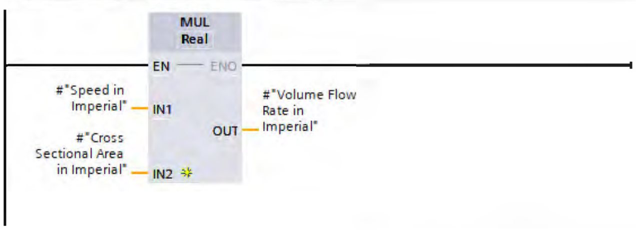
Network 4: For HMI display purposes.

Convert cross sectional area into square inches.



Network 5: Volume flow rate calculation.

Speed (ft/s) * Area (sqft) = Volume Flow Rate (ft3/s)



Network 6: Volume flow rate unit conversion to cim.

ft3/s -> in3/min