Introduction

This assignment involves designing an automated system to sort objects based on specified criteria, using a motor-controlled conveyor belt system equipped with sensors and actuators. The primary objective is to develop a system that can effectively categorize objects as they are fed from a loading chamber onto a 1-meter long conveyor belt. The system includes,

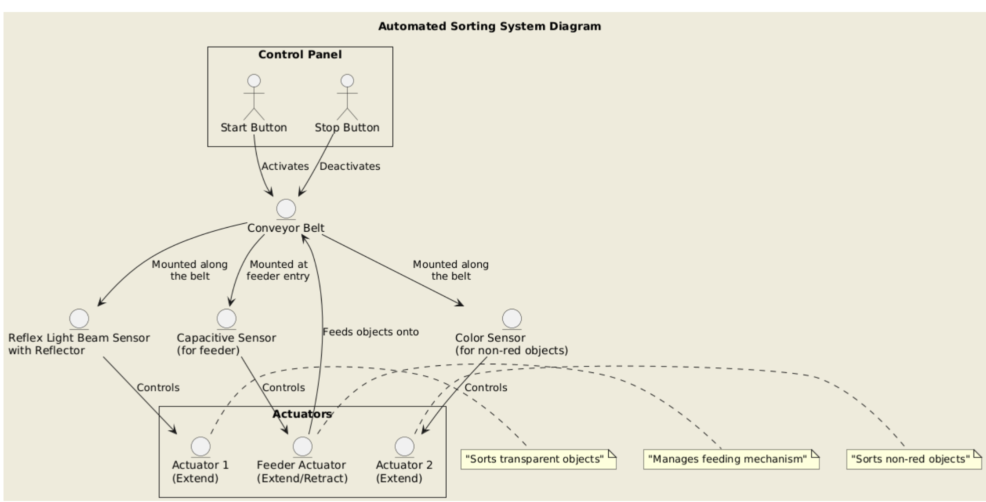
1. Feeder Mechanism
   This component stacks objects in a feeding chamber from which they are individually released onto the conveyor by an actuator.

2. Sorting Mechanism
   As objects move along the conveyor belt, they pass through various detection zones. Each zone is equipped with sensors and corresponding pneumatic actuators that sort the objects based on their physical characteristics and colors, as determined by the last digit of a student's ID:

   - 0, 3, 6: Sorts orange colored, metallic bottle caps.
   - 1, 4, 8: Sorts red colored, fluid-filled plastic cans.
   - 2, 5, 9, 7: Sorts red colored reflective packaging boxes.

The system operation is broken down into:

1. Detailed planning of the system setup and the selection of suitable sensors and actuators.
2. Programming the control system to coordinate the sensors and actuators for proper sorting.
3. Adjusting and testing the system in a controlled environment to ensure it meets the sorting requirements.



<u>Design Procedure</u>

1. Design Requirements

System Needs

The necessity for this system stems from the requirement to segregate red reflective boxes from a mix that includes transparent and non-transparent boxes, as well as red and non-red reflective types. Such sorting is critical in applications where the accurate classification of items can significantly streamline operational processes.

Outputs Desired

The desired output of the system is a sorted collection of red reflective boxes, effectively separated from other boxes at the end of the conveyor belt operation. This precise sorting is critical for subsequent packaging or manufacturing processes that require uniformity in material characteristics.

2. Data References

Sensor Selection and Specifications

Sensor Model	**Purpose**	**Sensing Technology**	**Range**	**Output Configuration**	**Additional Features**
Banner Engineering QS18EN6XLPC	Detects transparent objects on the conveyor system.	Polarized retro-reflective	Up to 3 meters, optimal for conveyor placement	Complementary PNP (sourcing)	Adjustment via potentiometer; IP67-rated housing
Rockwell Automation 46CLR ColorSight™	Identifies and differentiates non-red boxes from red ones	True Color Recognition	Effective sensing distance up to 65 mm	IO-Link communication	Can store up to seven colors; Software-based setup and adjustment

The Banner Engineering QS18EN6XLPC sensor is selected for its reliable performance in detecting transparent objects, utilizing polarized retro-reflective technology to minimize false triggers from other shiny surfaces. This sensor is well-suited for industrial settings with its robust IP67-rated housing, ensuring durability against environmental factors.

The Rockwell Automation 46CLR ColorSight™ sensor is ideal for its precise color detection capabilities, essential for distinguishing between red and non-red boxes. The IO-Link communication feature facilitates seamless integration with PLC systems, supporting real-time adjustments and enhancing the overall efficiency of the sorting system.

3. Analysis Steps

Inputs and Outputs Used

The system utilizes sensors and actuators as inputs and outputs to detect characteristics of the boxes and actuate sorting mechanisms.

I/O Type	Address	Description	Function
Input	I0.0	START	Initiates the conveyor belt system.
Input	I0.1	STOP_	Halts the conveyor and all actuations.
Input	I0.2	S1	Sensor for the extended position of Actuator 1.
Input	I0.3	S2	Sensor for the extended position of Actuator 2.
Input	I0.4	S3	Sensor for the retracted position of the Feeder actuator.
Input	I0.5	S4	Sensor for the extended position of the Feeder actuator.
Input	I0.6	RLBS	Reflex light beam sensor with reflector for detecting transparent objects.
Input	I0.7	ColorS	Color sensor for detecting non-red objects.
Input	I1.0	Cap	Capacitive sensor for detecting presence in the feeder.

Output	Q0.0	Conveyor	Controls the conveyor belt operation.
Output	Q0.1	Y1	Controls extension of Actuator 1 for sorting.
Output	Q0.2	Y2	Controls extension of Actuator 2 for sorting.
Output	Q0.3	Y3	Controls extension of the Feeder actuator.
Output	Q0.4	Y4	Controls retraction of the Feeder actuator.

Sequence of operation

Step	Operation	Description
1	Start/Stop Button Activation	The system is initiated by pressing the Start button, activating the conveyor belt. The Stop button halts the conveyor and all subsequent operations.
2	Feeder Mechanism Activation	When objects are in the stack and the feeder is retracted, the feeder extends to move objects onto the conveyor belt.
3	Feeding Objects onto Conveyor	After extending to place objects on the conveyor, the feeder actuator retracts, readying for the next set of objects.
4	Detection and Sorting of Transparent Objects	A reflex light beam switch (RLBS) detects transparent objects. Due to spatial constraints, a timer delays the actuator's activation until the object reaches the actuator's position on the conveyor.
5	Resetting Actuator 1	Actuator 1 extends to sort the transparent object and retracts once the object is completely clear, resetting for the next cycle.
6	Color Detection and Actuation	A color sensor detects non-red objects as they move along the conveyor. Upon detection, Actuator 2 is immediately activated.
7	Resetting Actuator 2	After Actuator 2 extends and sorts the non-red object, it retracts once the object has cleared its path, readying for the next object.

Selection of components

	Used	Reason
Actuator 1	Single acting	Single Acting cylinder was selected as there was no forces acting on the shaft / piston
Actuator 2	Single acting	Single Acting cylinder was selected as there was no forces acting on the shaft / piston
Actuator 3 (Feeder)	Double acting	Double Acting cylinder was selected as there are forces acting on the shaft / piston when more cylinders are on the stack of objects and requires force for return stroke
Identification of Red, Orange and green color	Color sensor	Color sensor used to distinguish between the color of cubes
Detection of Transparent / Reflective object	Reflex light beam sensor with polarization filter	Transparent objects will cause the laser ray to hit the reflector causing the light beam to switch by 90 degrees whereas the reflective object would not
Detection of object in the object stack	Capacitive proximity sensor	Capacitive sensor can detect non-metallic objects including refllective and transparent glass

Sensor location

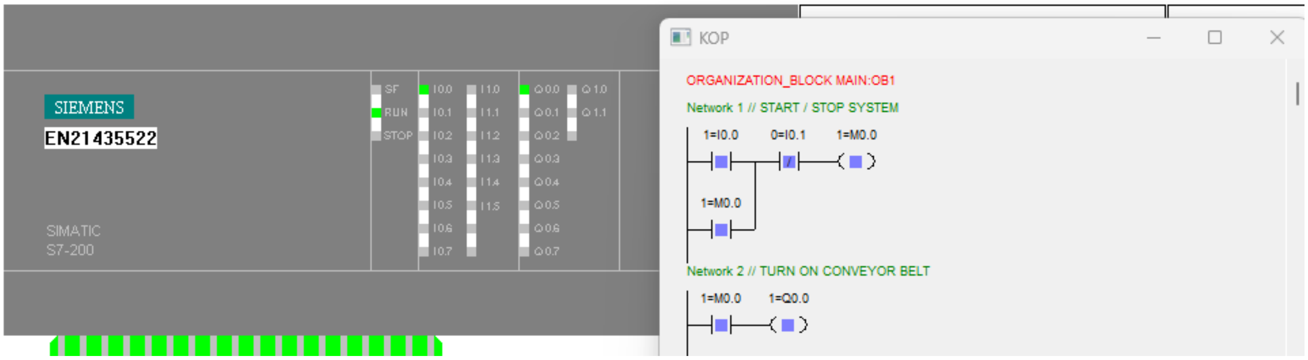
Component	Sensor location	Cause
Actuator 3	Through the stack of objects	Allowing the actuator to push the objects to the conveyor belt.
Capacitive sensor	Side the of stack	To detect if there are any objects in the stack
Actuator 3 Sensors (Feeder) (Ring magnet sensor)	Sensor on both ends of the shaft	To detect both ends of the stroke. Poition data from both locations will allow for seamless control of cylinder
Actuator 1, 2 Sensors (Ring magnet sensor)	Extended position of actuator	The position information of extended position is enough to control the extension of the actuators.
Reflex light beam switch	Before actuator 1	The reflex light beam switch and actuator both cannot be placed next to each other as the reflex
Actuator 1		

		light beam switch is used with a polarization filter. Therefore both sides of the conveyor belt are taken
Color sensor	Next to actuator 2 but top mounted on conveyor belt	Both sensors are placed perpendicular to the conveyor belt as it there is place to place both, one of side and and one on top.
Actuator 2	Next to color sensor but side mounted to conveyor belt	

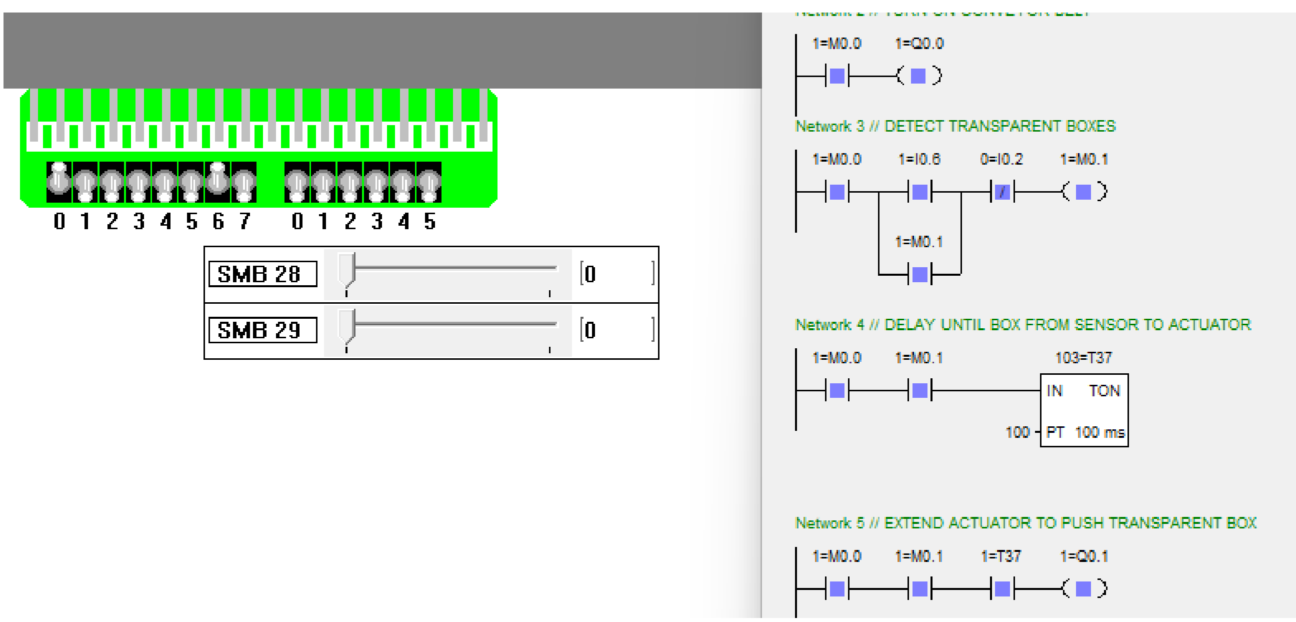
4. Simulation Results

S7-200

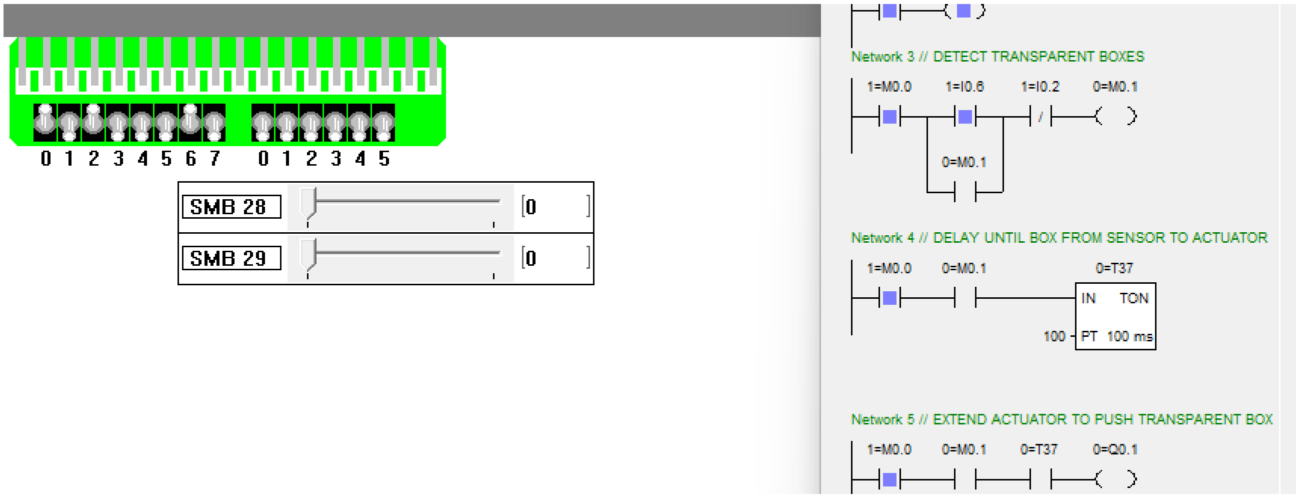
Start stop button and turning on of conveyor belt.



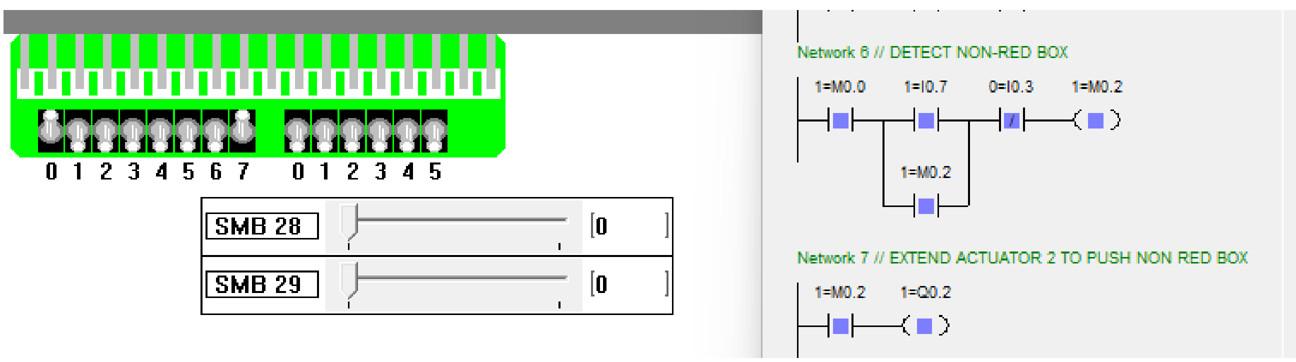
Furthermore, the transparent objects are detected using a reflex light beam switch with a timer as actuator cannot be placed same position. Therefore the reflex sensor signal is delayed and the actuator then activated once the transparent object reaches actuator position in conveyor belt.



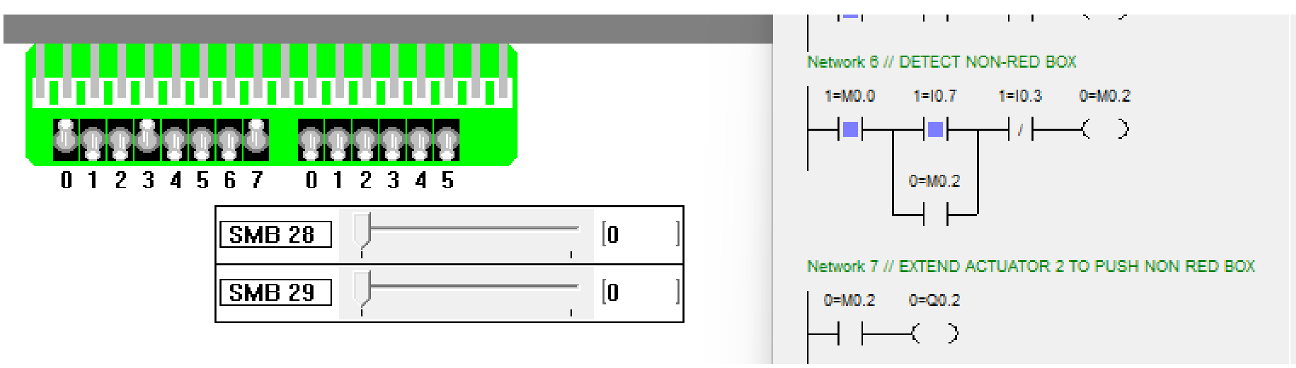
However, when the actuator 1 reaches extended position, the timer stops and the cylinder reaches retracted position.



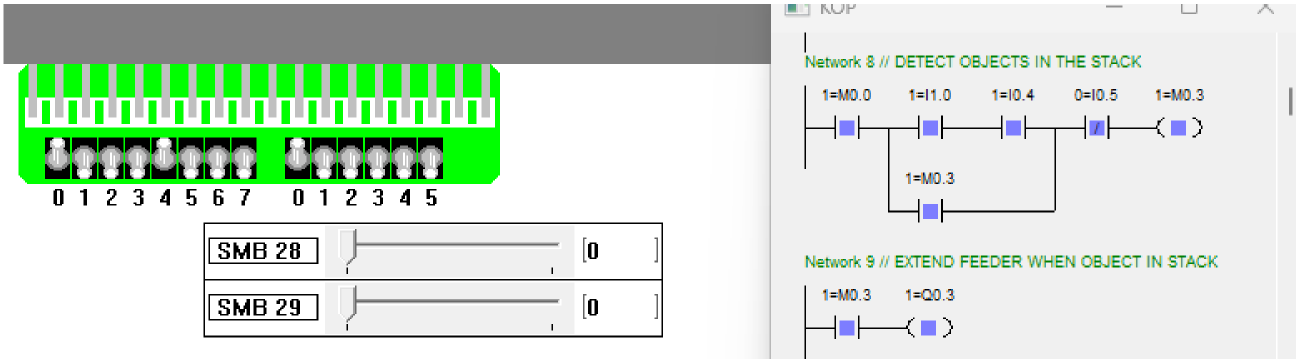
When a color other than red is detected, the 2nd actuator will immediately be activated.



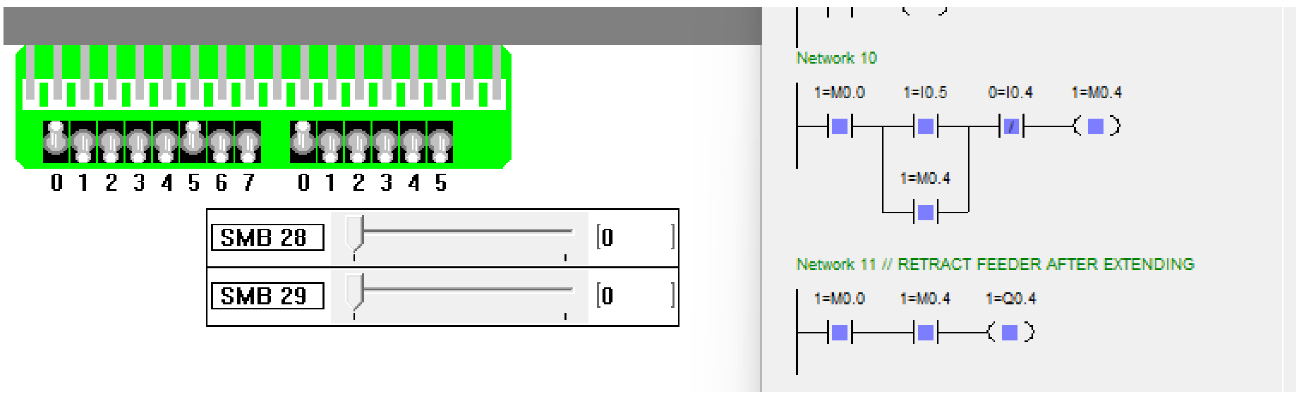
After the 2nd actuator is activated and it reaches extended position, the cylinder will retract accordingly.



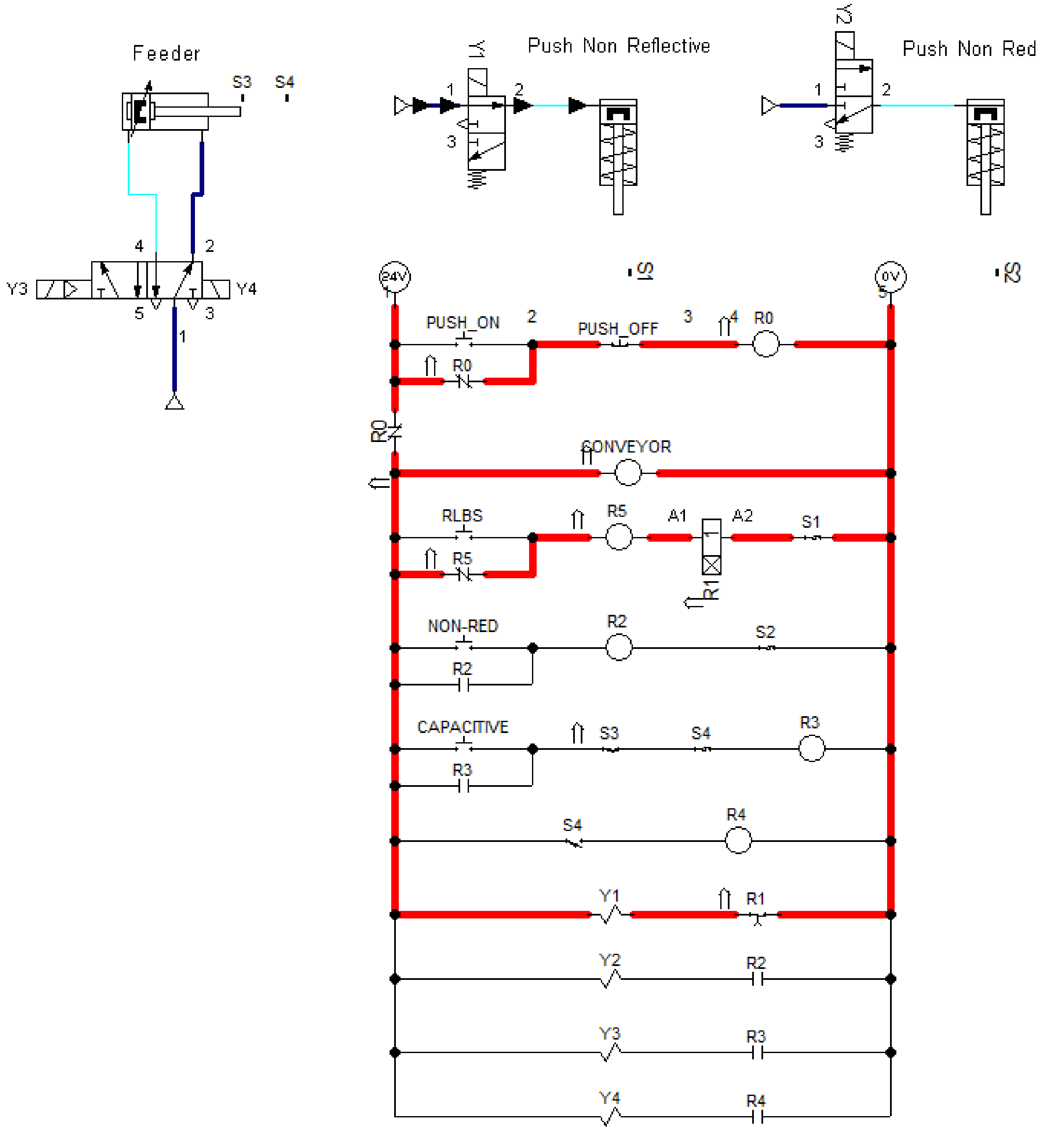
When the objects are in the stack and feeder is in retracted position. They feeder will extend.



Once the feeder has been extended, it will retract accordingly.



Fluid-Sim



The same circuit was implemented using electro-pneumatics in Fluidsim. This allows the cylinders to be completely automated. However the capacitive sensor, reflex light beam switch and the color sensor required input signals separately. As seen above, the simulation works as well.

5. Test Results

To test the automated sorting system, we will start by identifying the specific tasks that need to be done during the lab demonstration. This is important because the setup in the lab might be different from what we planned on paper. We'll list each task to make sure everything is set up correctly and all parts are ready for use.

Next, we will check all the inputs and outputs of the system. This means understanding how each part of the system, like the Start/Stop buttons, sensors, and actuators, works together to control the sorting process. By doing this, we can make sure that every component does its job right.

We will also go through the sequence of operations programmed into the system. This step is to make sure that every action in the system happens in the right order and works well to sort the objects correctly. Since the lab might have different equipment or limited components compared to what we planned, it's important to adjust our setup and use what is available. We will use the same approach we used in developing the simulations in this report to make these adjustments.

During the test, we will look closely at where each sensor and actuator is placed. They need to be in the best spot for detecting and sorting objects based on things like whether an object is transparent or what color it is. This helps the system sort objects accurately.

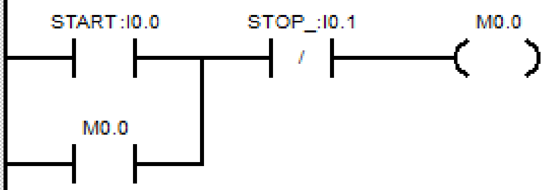
The PLC control code, which tells the sensors and actuators what to do, will also be tested. This code needs to run smoothly, making sure the conveyor belt starts, the feeder works properly, and the sorting happens without any problems. We will keep an eye on the system while it's running to catch any issues or unexpected stops.

6. Final Design

PROGRAM COMMENTS

Network 1 START / STOP SYSTEM

Network Comment

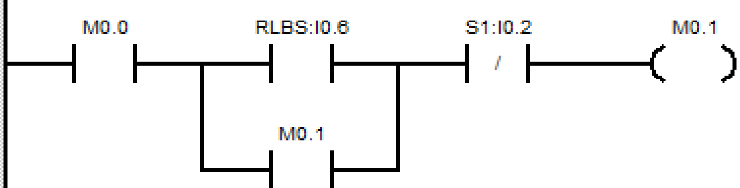


Symbol	Address	Comment
START	I0.0	start button
STOP_	I0.1	stop button

Network 2 TURN ON CONVEYOR BELT

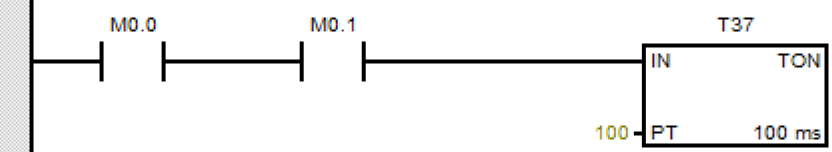
Symbol	Address	Comment
Conveyor	Q0.0	Conveyor belt

Network 3 DETECT TRANSPARENT BOXES

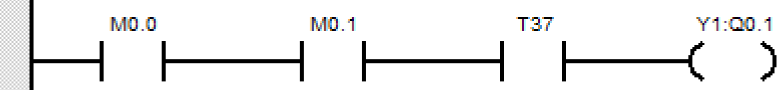


Symbol	Address	Comment
RLBS	I0.6	Reflex light beam sensor with reflector
S1	I0.2	Extended position of actuator 1

Network 4 DELAY UNTIL BOX FROM SENSOR TO ACTUATOR

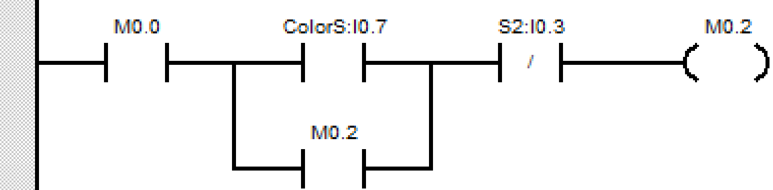


Network 5 EXTEND ACTUATOR TO PUSH TRANSPARENT BOX



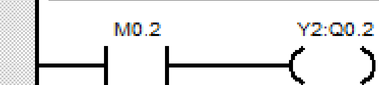
Symbol	Address	Comment
Y1	Q0.1	Extend Actuator 1

Network 6 DETECT NON-RED BOX



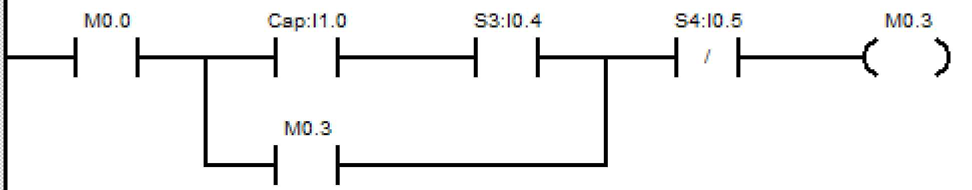
Symbol	Address	Comment
ColorS	I0.7	Color sensor to detect non-red objects
S2	I0.3	Extended position of actuator 2

Network 7 EXTEND ACTUATOR 2 TO PUSH NON RED BOX



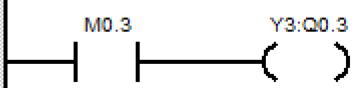
Symbol	Address	Comment
Y2	Q0.2	Extend Actuator 2

Network 8 DETECT OBJECTS IN THE STACK



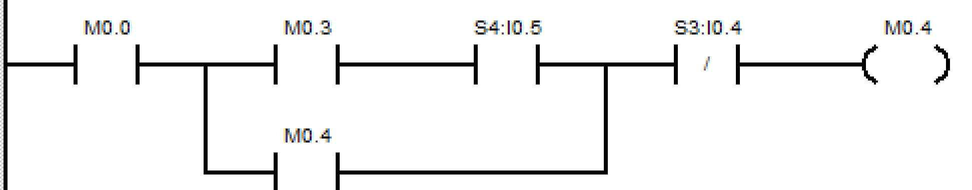
Symbol	Address	Comment
Cap	I1.0	Capactive sensor for feeder
S3	I0.4	Retracted psotion of Feeder actuator
S4	I0.5	Extended position of Feeder actuator

Network 9 EXTEND FEEDER WHEN OBJECT IN STACK



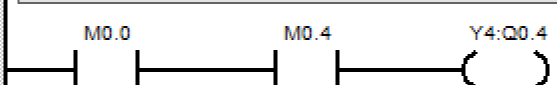
Symbol	Address	Comment
Y3	Q0.3	Extend Feeder

Network 10



Symbol	Address	Comment
S3	I0.4	Retracted psotion of Feeder actuator
S4	I0.5	Extended position of Feeder actuator

Network 11 RETRACT FEEDER AFTER EXTENDING



Symbol	Address	Comment
Y4	Q0.4	Retract Feeder

Discussion and Conclusion

Reflection

This project presented a unique challenge, designing an automated system to sort various objects based on their physical characteristics and colors. The primary objective was to develop a reliable system capable of accurately categorizing objects as they were fed from a loading chamber onto a 1-meter long conveyor belt. This system, comprising a feeder mechanism and multiple sorting actuators integrated with sophisticated sensors, was carefully planned and executed from conceptualization through to simulation and testing phases.

Throughout the development process, from the initial system setup to the programming of the control system to testing the system using simulators. We gained significant insights into the complexities of building automated sorting systems.

Challenges

One of the major challenges was deciding how and where to place the sensors. The placement needed to ensure optimal detection of object characteristics while accommodating the mechanical movements of the conveyor and actuators. This required several iterations of placement and testing to find the most effective locations that would not interfere with the system's operations or the objects' movement.

Coming back to programming after a period of inactivity posed its own set of challenges. There was a learning curve involved in re-familiarizing with PLC programming and understanding how to integrate the inputs from various sensors into a cohesive control system that reliably managed the actuators. This process took significant time, as it required refreshing knowledge and skills to ensure the programming accurately reflected the operational needs of the sorting system.

References

1. Banner Engineering Corp., "QS18EN6XLPC Photoelectric Sensor," Datasheet, [Online]. Available: https://www.mouser.com/ProductDetail/Banner-Engineering/QS18EN6XLPC?qs=vvQtp7zwQdOjW0zCgn74vQ%3D%3D. [Accessed: Nov. 3, 2024].

2. Rockwell Automation, "46CLR ColorSight™ True Color Sensor," Product Profile, [Online]. Available: https://literature.rockwellautomation.com/idc/groups/literature/documents/pp/46clr-pp001_-en-p.pdf. [Accessed: Nov. 3, 2024].

3. Banner Engineering Corp., "WORLD-BEAM QS18E Series," Datasheet, [Online]. Available: https://info.bannerengineering.com/cs/groups/public/documents/literature/136564.pdf. [Accessed: Nov. 3, 2024].

Appendix

WORLD-BEAM QS18E Clear Object Detection

Quick Start Guide

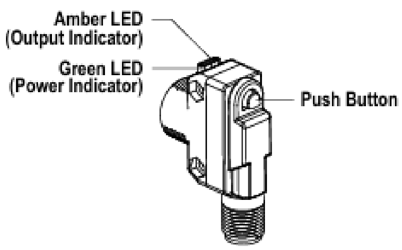
Expert™ Coaxial Polarized Retroreflective Sensor for Clear Object Detection

This guide is designed to help you set up and install the QS18 Clear Object Detection. For complete information on programming, performance, troubleshooting, dimensions, and accessories, please refer to the Instruction Manual at *www.bannerengineering.com*. Search for p/n 194469 to view the Instruction Manual. Use of this document assumes familiarity with pertinent industry standards and practices.

WARNING: Not To Be Used for Personnel Protection

Never use this device as a sensing device for personnel protection. Doing so could lead to serious injury or death. This device does not include the self-checking redundant circuitry necessary to allow its use in personnel safety applications. A sensor failure or malfunction can cause either an energized or de-energized sensor output condition.

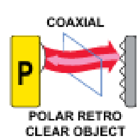
Overview



The Banner QS18 sensor is a high performance clear object detection sensor. The polarized coaxial optical design ensures reliable detection of transparent, translucent, and opaque targets at any distance between the sensor and the reflector. Low contrast sensing applications include PET bottles, glass containers, and shrink wrap. The sensor can also be used to detect optical surfaces such as: LCD panels with built in polarizing films, solar panels, and semiconductor wafers.

Indicators (Two LEDs: One Green, One Amber)		
Sensor Condition (Run Mode)	**Green LED**	**Amber LED**
Output OFF	ON	OFF
Output ON	ON	ON
Notification — Sensor needs to be reconfigured for reliable detection	Flashing at 5 Hz	ON/OFF
Notification — Push button has been locked out	Flashes 4 times and returns to solid on	ON/OFF

Models

Models	Mode	Range	Output	Connector [1]
QS18EN6XLPC		0 to 1.3 m (0 to 4.2 ft) on BRT-40X19A 0 to 2.0 m (0 to 6.5 ft) on BRT-51X51BM 0 to 3.0 m (0 to 9.8 ft) on BRT-92X92C	NPN	2 m cable (6.5 ft)
QS18EP6XLPC			PNP	

Light Set

Use Light SET for low contrast applications. Use either the push button or remote input wire procedure to configure the sensor.

Example Applications For Offset Percentages	
8%	Recommended for very low contrast applications with stable environmental conditions.
16%	Recommended for most clear object detection applications in typical machine industrial environments.
32%	Recommended for high contrast detections such as brown or green bottles, or opaque objects. This setting tolerates environmental challenges such as vibrations and dust build-up.

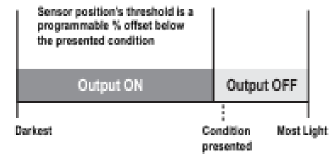
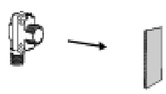


Figure 2. LIGHT SET sensing mode in dark operate

Table 1: LIGHT SET Push Button Configuration

Setup	Action	Result
Clear the light path to the reflector. 	Press and hold the push button 2 to 4 seconds. 	**<u>LIGHT SET Configuration Accepted</u>** **Green LED Indicator:** Flashes 3 times. **Green and Amber LED Indicators:** Acceptance flash - both LEDs flash 5 times rapidly in unison. The sensor returns to Run mode with the new settings. **<u>LIGHT SET Configuration Not Accepted</u>** If there is not enough return signal, the sensor will perform in DARK SET indicated by the green and amber LED indicators flashing in unison 2 times followed by the green and amber LED indicators flashing rapidly in unison 5 times.

Dark Set

Dark SET (maximum operating range) is the factory default setting and provides maximum sensing range, ease of alignment, and reliable detection of opaque objects. Dark Set provides a fixed threshold whenever the sensor is taught an obstructed view.

> **Note:** The sensor's light spot is made brighter for 60 seconds to assist in aligning the sensor to the reflector. This is particularly useful for long range applications.

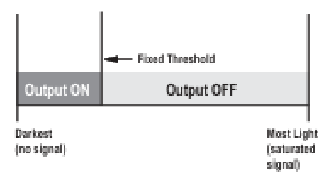
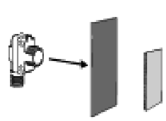


Figure 3. DARK SET sensing mode in dark operate

Table 2: DARK SET Push Button Configuration

Setup	Action	Result
Block the light path to the reflector. 	Press and hold the push button 2 to 4 seconds. 	**<u>DARK SET Configuration Accepted</u>** **Green and Amber LED Indicators:** Flash 2 times. **Green and Amber LED Indicators:** Acceptance flash - both LEDs flash 5 times rapidly in unison. The sensor returns to Run mode with the new settings. **<u>DARK SET Configuration Not Accepted</u>** If there is too much return signal, the sensor will perform in LIGHT SET indicated by the green LED indicator flashing 3 times followed by the green and amber LED indicators flashing rapidly in unison 5 times.

46CLR ColorSight™ True Color Sensor

Advanced, high-performance color sensing

Features and Benefits

- Three models to address your needs:
  - Glare suppression
  - Small spot size (for small object detection)
  - Long range
- Built-in distance correction technology confirms consistent color detection
- Internally stores up to seven colors in color match mode and unlimited colors by using IO-Link when connected to CompactLogix™
- Access true RGB color and intensity values using IO-Link
- Nine adjustable tolerance levels provide additional flexibility in installation
- Three discrete outputs with auto PNP/NPN
- IP67 and IP69 zinc die cast rated enclosure
- Embedded IO-Link communication protocol helps minimize downtime and increase productivity

What is IO-Link?

IO-Link is a worldwide open-standard peer-to-peer serial communication protocol (IEC 61131-9) that allows sensors to easily integrate into The Connected Enterprise.

Benefits of IO-Link technology include:

- Reduced inventory and operating costs
- Increased uptime/productivity
- Simplified design, installation, setup and maintenance
- Enhanced flexibility and scalability
- Device specific parameters

IO-Link

The new Allen-Bradley® 46CLR ColorSight™ True Color Sensor – like its ColorSight counterparts – was designed to perform the sensing operations commonly found in the automotive, food and beverage, pharmaceutical, and plastics, among other industries. This sensor offers enhanced performance in a compact, cost-effective package and addresses an even wider range of your applications.

The 46CLR is a color sensing solution featuring patent pending distance correction technology that confirms consistent color detection at ranges up to 65 mm. Additional features include internal storage of up to seven colors and nine adjustable tolerance levels for optimal application flexibility.

The 46CLR is also a smart sensing solution with embedded IO-Link functionality that easily integrates into The Connected Enterprise. That means the 46CLR can deliver sensor health and application data directly into a control system to help minimize downtime and increase productivity.

46CLR ColorSight IO-Link Features and Benefits

Triggered for Seven Color Channels: provides indication on each of the available color channels – three discrete outputs and four virtual outputs

Two Data Process Maps: data map 0 indicates the individual status of internally stored colors within the sensor, while data map 1 displays the RGB+I information

Red, Green, Blue and Intensity: provides the raw value of red, green, blue and intensity as a process data map

Signal Strength: provides the raw signal strength value reflected by the color target

Location Indication: helps distinguish sensors in applications where you may need to identify in a large machine

Multiple Profiles: can be set up and stored to support multiple machine configurations. Multiple profiles enable configuring the sensor one time and having the capability to change products instantly without manual intervention.

Internal Temperature: helps you determine if the sensor is operating close to its minimum and maximum temperature range

Counter: counts the number of times the target has been detected

Timers: indicates the amount of time the target was present or absent, which can be used to determine how fast your system is operating

Averaging Filter: this parameter changes the number of samples that the sensor takes to stabilize the measurement. This averaging operation provides a consistent representation of the measurement.

User Interface Locks: helps prevent undesired or unauthorized changes of the sensor settings

Product Selection

Model	Operating Voltage	Light Source	Sensing Distance	Outputs	Inputs	Catalog No.
Glare Suppression	18…30V DC	White LED	18…32 mm	3 x PNP	Configurable Trigger and Push Button Lock	46CLR-D5LAC1-D5
Small Spot Size			18…60 mm			46CLR-D5LAC2-D5
Long Range			20…150 mm			46CLR-D5LAC3-D5

Product Specification

Specifications			
Certifications	cULus and CE marked for all applicable directives		
User Interface		**IO-Link**	
Status Indicators	LCD display with Green and Red LED backlights	Communications Mode	COM2
Electrical		Cycle Time, min	4 ms min.
Adjustments	3 push buttons	Process Data Bit Length	48 bits (6 bytes)
Operating Voltage	18…30V DC	Specifications	IO-Link 1.1
Output Mode	Programmable Light Operate or Dark Operate	**Mechanical**	
Output Type	PNP or NPN programmable	Enclosure Rating	IP67 and IP69 rated enclosure
Response Time	0.3…0.333 ms	Enclosure Material	Zinc die-cast, matt chrome
		Operating Temperature	-20…+55 °C (-4…+131°F)

Accessories

Description	Catalog No.
L-Shaped Mounting Bracket	60-BDMS-LS
5-pin M12 (Micro) QD Shielded Cordset, 2 m	889D-F5EC-2