INDUSTRIAL MAINTENANCE

PLC Fundamentals for Maintenance Engineers

CP2388

www.matrixtsl.com

Introduction

INTRODUCTION

This curriculum is designed to introduce students, apprentices, and early-career technicians to the core components, wiring methods, and signal types found in real industrial control panels. If you're new to PLCs or have never looked inside a control cabinet before, this program offers a hands-on pathway to understanding how industrial automation systems are built, wired, and maintained in practice.

Curriculum

The course is divided into 12 worksheets. Each worksheet focuses on a specific component or concept, such as emergency stops, indicator lights, relays, sensors, and input or output types. As you progress, you will develop the skills needed to work safely around PLC-controlled systems and understand how inputs and outputs interact in a functioning panel.

This curriculum assumes no prior experience with programming or electrical systems. It is ideal for learners studying T Levels, BTECs, or completing engineering apprenticeships in maintenance, installation, and repair. The aim is to build confidence in identifying hardware, tracing signals, and understanding how a PLC communicates with the devices connected to it.

Work through each worksheet carefully and take your time with the hands-on tasks. By the end of the course, you will have a clear and practical understanding of PLC fundamentals from a maintenance engineer's point of view.

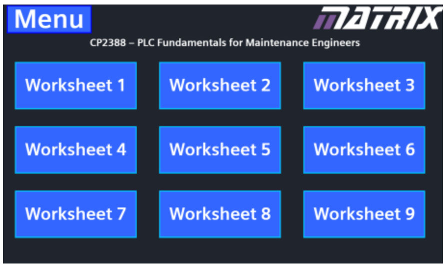
WORKSHEETS

Worksheets

Worksheet 1 – Simple PLC Systems

The PLC Fundamentals Training rig in front of you represents a basic industrial control system like those used in factories. It includes real components such as push buttons, lights, motors, and a Siemens PLC that controls them. This worksheet introduces the core concept of how a PLC processes inputs to control outputs.

Over To You



1. When on the Home Page, press the Start button to enter the Main Menu, select Worksheets and then Worksheet 1.
2. Observe the picture in the centre of the screen.
   - It displays a simple PLC control system, where a Siemens PLC controls a lamp above the panel.
3. Press & hold button I0.
   - Observe the light change turn on Red.
4. Press & Release the button a few times
   - You should observe the LED on the left & right of the image, turning on and off.
   - You should also observe the LEDs on the PLC turning on and off.

Worksheets

So What?

When you were pressing the button at Input 0, the output was only active whilst you held the button. This is called a momentary button – it only works whilst pressed down. When you released the button, the output turned off. This is a momentary button. The PLC code here is looking for the input signal and only turning on the output whilst it has this signal.

Simple PLC systems are the first step into the world of automation. They use a PLC (programmable logic controller) to turn things on and off based on what it's been programmed to do, like switching on a light when you press a button.

These systems have only a few parts and no complicated logic. They're easy to understand and perfect for learning how basic industrial control panels work. In real life, they're used for things like turning fans or alarms on and off safely.

Key Takeaways

- Simple PLC systems control basic on/off actions, like switching on a light with a button.
- They consist of a few parts: push buttons, indicator lights, and a PLC.
- The PLC processes simple instructions – if the button is pressed, turn the light on.
- You can see the PLC's internal logic in action as the LEDs on the PLC itself turn on and off.
- These simple systems are the building blocks for understanding more complex industrial processes.

Student Handbook

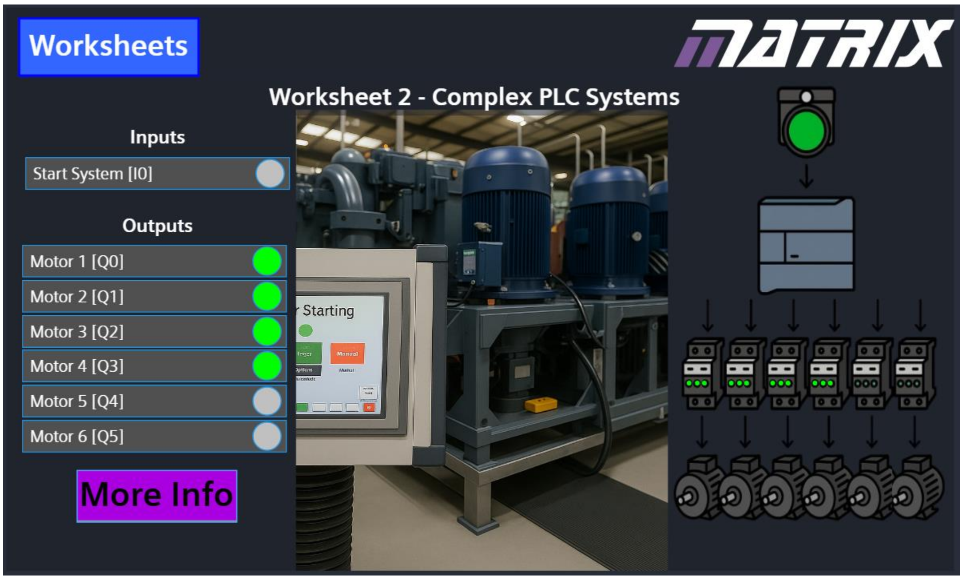
Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 2 – Complex PLC Systems

Complex PLC systems control multi-step processes using sensors and outputs. They're used in real industrial environments to safely sequence tasks, like lifting a bridge or moving parts on an assembly line. In this worksheet, you'll see how the PLC manages multiple signals and safety checks to complete a process step by step.

Over To You



1. Navigate to Worksheet 2 on the HMI
2. Press the button I0 again as you did in Worksheet 1 but this time don't hold it down
   - You will now see the output lights sequence themselves on from Output 0 (Q0) to Output 5 (Q5).
3. As the lights are turning on, press Input 2 (I2), the red button
   - This interrupts the sequence and turns it off.
4. Observe the Inputs and Outputs changing on the HMI
5. Notice that the HMI does not show I0 as on, as it is not.
   - The PLC has received and latched the start command

So What?

The physical system (i.e. the wiring) has not changed but the behaviour has. In worksheet 1, the logic was basic, if we get input 0, then turn on the 3 outputs.

Now we're dealing with a more complex system. If we get input 0, latch that as a start command, and then start a sequence to turn on one output at a time, until they're all on. Releasing Input 0, makes no difference anymore, due to the PLC program - the command is latched on.

The PLC will only break this command if you press the red button on Input 2 or if you press the Emergency Stop (more on that later).

Remember: Our button is still a momentary button, but it is being latched by the PLC software.

This is an example of a complex PLC system. As you progress in Industrial Maintenance and fault-finding or troubleshooting, you will need to understand what type of circuit you have and what's happening or supposed to be happening in the PLC code. You will rarely work on simple PLC systems, most will be a lot more complicated than what we've looked at in this worksheet.

Key Takeaways

- Complex PLC systems use multiple inputs, outputs, and steps to complete a process.
- The same hardware can do simple or complex tasks based on the PLC's program.
- A start button signal can be **latched** in the PLC software so the process keeps going without holding the button down.
- Pressing an emergency or stop button can interrupt the process, adding a layer of safety.
- These systems rely on sensors and programmed logic to work safely and reliably.
- In real industrial environments, most PLC systems use sequences and latches to manage complex tasks.

Worksheets

- Understanding how a process is programmed and how to read inputs and outputs is key to troubleshooting and fixing faults.

Student Handbook

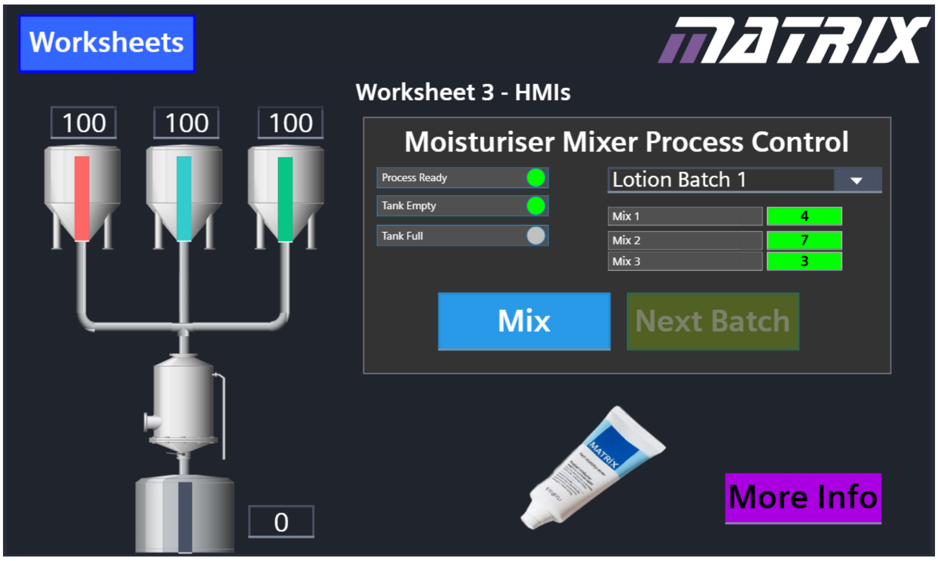
Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 3 – HMIs

A HMI is the touchscreen or control panel you see in front of industrial systems. It's how operators monitor what's going on in a process and send commands to the PLC. Operators use HMIs to navigate menus, view real-time input and output data, and see how alarms or errors show up. HMIs are essential for operators to safely and effectively control machines and processes.

Over To You



1. Navigate to Worksheet 3 on the HMI.
2. Observe the three tank levels at the top left.
3. Observe the bottom tank.
4. Select the dropdown list on the top right and change the batch from Lotion to a different batch (Cream, Serum or Cleanser).
5. Press the Mix button and observe how the liquids drain from the three tanks into the bottom tank.
   - During the mixing process, the controls will be inactive (greyed out).
   - Once the mix is done, the Next Batch button will become active again.
6. There are three parameters labelled Mix 1,2 and 3. Adjust them by increasing or decreasing them. Observe how they affect the tanks draining.

Worksheets

So What?

This is a typical HMI screen you will find in any factory, anywhere in the world. This particular example is of a batch mixing process. There are four tanks, three with the ingredients and the fourth is the final mixed product. This is essentially how we get most of our food, drinks, chemicals, cosmetics and many other products.

Operators, not Maintenance Engineers, use these screens daily to control a process. However, Maintenance Engineers will need to use during maintenance of the machine to test and troubleshoot.

Sometimes you can adjust certain parameters on the screen, other times the on-screen components are for information purposes only. This is not always obvious, reading the User Manual that comes with the HMI or System is essential.

Key Takeaways

- HMIs are essential for operators to monitor and control industrial processes safely and effectively.
- HMIs show real-time data like tank levels and alarms and allow you to adjust process parameters.
- In batch mixing processes, HMIs display how ingredients are combined and let you change batch settings.
- Operators use HMIs every day, but Maintenance Engineers use them too during troubleshooting and testing.
- Not all HMI screens allow changes. Some only display data, while others let you adjust parameters.
- Reading the User Manual for your specific HMI is crucial to understanding how to safely operate and maintain the system.

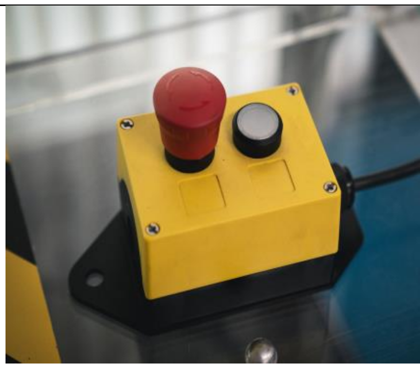
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 4 – Emergency Stops

An Emergency Stop (E-Stop) is a safety button that quickly stops a machine or system when there is an emergency. It helps keep people safe and prevents damage to equipment. An E-Stop is not the same as a normal stop button. It should only be used in emergencies, not to turn off the machine during normal use.



Over To You

1. Navigate to Worksheet 4 on the HMI
    a. This is the same system we explored in Worksheet 3, but with less on the screen so we can focus on E-Stops.
2. Locate the emergency stop button at the top of your training rig.
3. Start the mix;
    a. When the tank is approximately half full, press the E-Stop.
4. Read the Alarm banner that appears at the bottom of the screen.
5. Tap on the Alarm banner to be taken to the Alarm page.
    a. Find the emergency stop alarm in the table
6. Reset the emergency stop by twisting it left until it is no longer pressed down.
7. Press the blue reset button next to the emergency stop button.
    a. Observe that the alarm for the emergency stop has been cleared.
8. Navigate back to the Main Menu page and then to the Faults page.
9. Find the emergency stop fault, it should be cleared.

10. Press the emergency stop again and observe the fault on this page
11. Reset the fault by pressing the Reset button on the HMI this time.

So What?

E-Stops have **dual channels** or two inputs into the control system, to make them reliable and safe:

- **Two Contacts**: The E-Stop button has two sets of contacts. Both must be closed for the system to function. When pressed, both contacts open and the system stops. Even if only one were to open, the system would still stop. This is done as a redundancy measure.
- **Reset Needed**: After using an E-Stop, the emergency stop button must be reset and the reset button must be pressed once before the system can start again.

Regularly inspect the E-Stop for damage or loose parts and test it during downtime to ensure it functions properly. Never cover or tamper with one.

Key Takeaways

- E-Stops are for emergencies, not regular use.
- They have two safety circuits to make sure they work.
- Regular checks and tests keep them reliable.

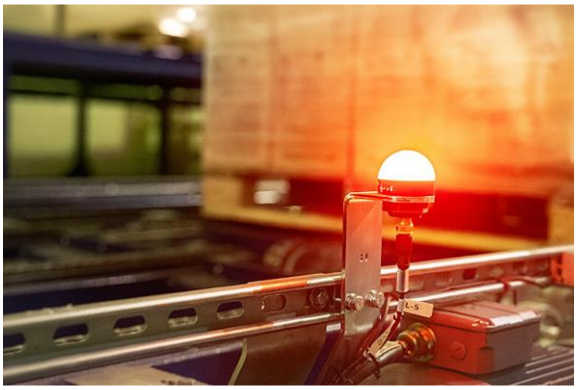
Knowing how to use an E-Stop can help keep everyone safe and the system running well.

Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheet 5 – Status LED

The Status LED shows what the system is doing. It lights up in different colours to show if things are working normally or if there's a problem. This makes it easier for maintenance teams to spot issues early, fix them quickly, and keep the system running safely and reliably.



Over To You

1. Navigate to worksheet 5 on the HMI.
2. Locate the status LED on your training system.
3. Turn on the 'Basic Mode' switch
    a. Note the colour of the status LED on the screen and on the PLC training rig.
    b. If there is a fault or the emergency stop is pressed, the status LED will be red. If everything is all clear and the system is healthy, the status LED will be green.
4. Press the emergency stop button and then note the change in colour of the LED.
5. Turn off the basic mode switch and activate the Enhanced mode.
6. Note the same functionality of the Status LED. Press the emergency stop button and confirm the Status LED behaves as it did before.

7. Now press the Start button and observe how the Status LED reacts to the motor starting.
8. Turn off the motor by pressing the Stop button.
9. Turn off Enhanced mode and activate the Live Process mode.
10. Start the process by pressing the Start button and then observe how the Status LED reacts to the bottles passing by.
11. Activate Fast Processing by pressing the switch.
    a. Take note of the different types of bottles passing along the conveyor.
12. Observe how the Status LED reacts to OK and defective bottles.

So What?

In industry, you'll need to know how to read a system's status at a glance. Status LEDs are one of the fastest ways to do that. Whether the machine is healthy, starting up, running, or in fault, the colour and flashing pattern of the LED can tell you a lot if you know what to look for.

This worksheet gives you a chance to see how different LED behaviours can represent different system states. But remember, these are not official names or universal standards. Every machine can be programmed differently. That's why reading the machine manual and understanding how the Status LED is controlled by the PLC logic is essential.

You'll come across systems where flashing red means a fault or flashing green means normal processing. Others might behave completely differently. Being confident in reading these signals and tracing them back to PLC logic is a core skill in maintenance and automation.

This exercise helps you start building that instinct. By observing the LED in Basic, Enhanced, and Live Process modes, you'll begin to see how visual feedback links to system behaviour. That's the kind of real-world knowledge that sets you apart on the shop floor.

Key Takeaways

- Status LEDs show machine state at a glance
- Colours and flash rates mean different things
- These modes are examples, not official standards
- Always check the machine manual and HMI
- LED behaviour is set in the PLC program
- Understanding LEDs helps with fault finding

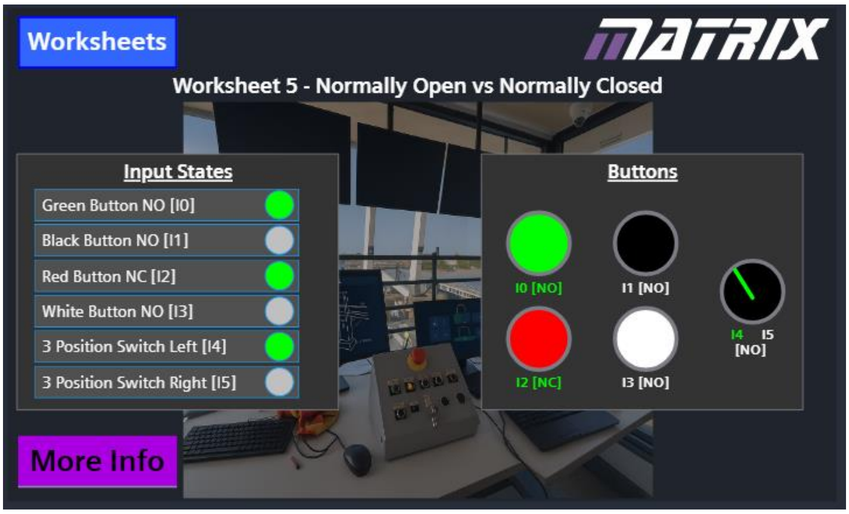
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheet 6 – Normally Open vs Normally Closed

Push buttons or control contacts can be normally open (NO) or normally closed (NC). An NO contact only sends a signal when pressed, while an NC contact is active until it's pressed. This difference helps ensure safe and reliable control in industrial automation systems.

Over To You



1. Navigate to worksheet 6 on the HMI.
2. Observe the state of the Inputs shown on screen (Green text means the input is on, White off).
3. Press & hold the green button on the training rig labelled Input 0.
    - Overserve the HMI screen show the input changing state.
4. Press & hold the black button labelled Input 1.
    - Observe the HMI display I1 changing state as you press & release.
5. Observe the current state of Input 2, the red push button on the HMI.
    - The input should be on even though you're not pressing the button.
    - Press Input 2 and observe the state of the Input on the HMI.
6. Press in Input I3 and observe the state change on the HMI.
7. Change the switch position of I4/I5, observe the inputs I4 and I5 turning on and off.

Inputs on HMI:

- **I0 [NO]:** Normally open. Off by default, turns on (green) when you press and hold the green button.
- **I1 [NO]:** Normally open. Off by default, turns on (green) only while you hold the black button.
- **I2 [NC]:** Normally closed. On (green) by default because it's an NC input. Pressing the red button interrupts the circuit and the input turns off (white).
- **I3 [NO]:** Normally open, latching push button. Pressing it toggles its state. It stays on until pressed again to turn off.
- **I4 [NO] and I5 [NO]:** Controlled by a 3-position switch:
    - **Left position:** I4 on (green), I5 off (white).
    - **Middle position:** Both off (white).
    - **Right position:** I4 off (white), I5 on (green).

Understanding the difference between normally open (NO) and normally closed (NC) push buttons and contacts is critical in industrial automation.

In industrial maintenance, this knowledge isn't just about wiring, it's about reading and interpreting system status correctly. On I/O or mimic screens, you need to know whether an input should be on or off when the button is not pressed.

For NO contacts, the input will show off until pressed/closed; for NC contacts, the input is on until pressed/opened. If you don't understand this, you might think there's a wiring fault or a problem with the input device. By knowing how these contacts work, you'll know what to expect and can quickly tell whether the system is behaving as designed or if there's an issue that needs fixing.

Key Takeaways

- NO vs. NC Contacts: Normally Open (NO) contacts are off until pressed, while Normally Closed (NC) contacts are on until pressed.
- Input Behaviour on HMI: Green means on, white means off. Knowing which is expected helps you spot faults quickly.
- Reading I/O States: For example, Input 2 (NC) stays on by default, while Inputs 0, 1, 3, 4, and 5 (NO) are off until action is taken.
- Why It Matters: In maintenance, you'll face real-world scenarios where misinterpreting these states can lead to downtime or unsafe conditions.
- Next Steps: Use this knowledge to troubleshoot, wire panels safely, and ensure the system operates as intended.

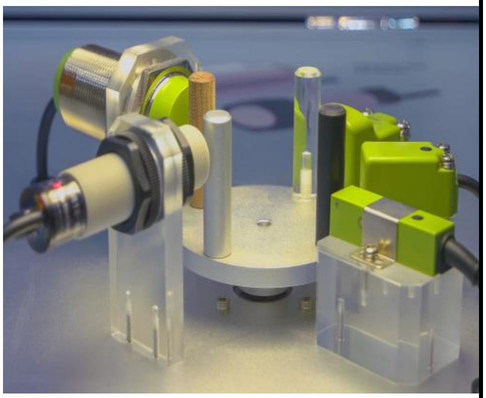
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

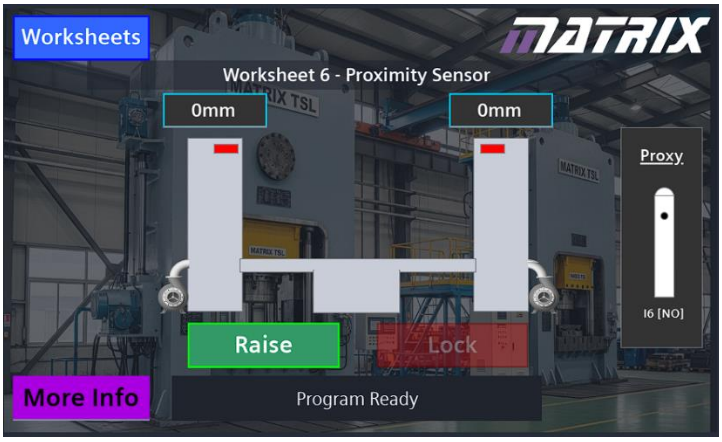
Worksheet 7 – Proximity Switch

A proximity switch detects an object's presence without contact, making it ideal for automation, positioning and safety systems. Maintenance engineers should know how they work to troubleshoot misalignments or faults, otherwise false triggers can cause machine stoppages or safety hazards. We use inductive sensors to detect metal objects.



Over To You

1. Navigate to worksheet 7 on the HMI.
2. Locate the proximity sensor (I6) on your training system.
    a. Ensure the proximity sensor is not currently triggered on. This can be verified by checking there is no LED turned on, on the physical sensor or by checking the HMI screen for worksheet 6. On the far right is the proximity sensor. If it's all white, with no green, then it is off.



    b. If the sensor is triggered on, then turn it off by removing the metal it is currently detecting.
3. Start the program by clicking the green Raise button.
4. Watch as the Forging Press raises up from 0mm to 15000mm. Take note of the position of the two red locking pins at the top of each side of the press.
5. Press the Lock button on the screen to begin the locking sequence. This will lock the press in the air and allow maintenance to go underneath the press.
6. You should now see a fault on the screen as although we told the system to begin locking the Press, the system did not detect the locking chocks as

engaged. This is because the system is waiting to detect the large metal locking pins using a proximity sensor.

7. Restart the system by clicking the Orange Reset button in the bottom right and get back to the locking stage.
    a. This time, ensure you place a metal object in front of the proximity sensor after clicking the Lock button, to simulate the system detecting the locking pins as engaged.
8. Observe what happens to the red locking pins on the top of the press as you trigger the proximity sensor.

So What?

Proximity switches detect the presence of metal objects without physical contact, making them crucial for safety and reliability in automated systems. In this exercise, the inductive proximity sensor confirms that the locking pins on the forging press are properly engaged. If the sensor doesn't detect the pins, the system generates a fault and stops, preventing the press from moving into an unsafe state.

Types of proximity sensors:

- Inductive – detects metal objects only
- Capacitive – detects both metal and non-metal materials
- Photoelectric – uses light to detect objects

Maintenance engineers must know how these sensors function and how to diagnose common faults like misalignment, incorrect positioning, or false signals. During troubleshooting, engineers often simulate sensor detection using a separate metal object to verify the sensor is working correctly. Accurate positioning and regular verification of sensor operation ensure safe and efficient system performance, especially in safety-critical applications like mechanical locking.

In this hydraulic press simulation, the proximity sensor acts as a critical safety interlock. It verifies the press platen is correctly locked into position by the safety chocks before allowing the system's motors to idle. Without reliable proximity sensing, the press would not confirm a safe, mechanically locked state, potentially leaving the system at risk.

Key Takeaways

- Proximity sensors detect objects without physical contact, improving reliability and reducing wear.
- Inductive sensors specifically detect metal objects, ideal for safety interlocks.
- Misalignment, poor mounting, and wiring faults can cause false signals and system stoppages.
- Sensors are often manually triggered with metal objects during troubleshooting.
- Correct sensor selection, positioning, and regular checks are essential for safe operation.

By understanding proximity switches, maintenance engineers can prevent system failures, improve accuracy, and ensure safe and efficient machine operation.

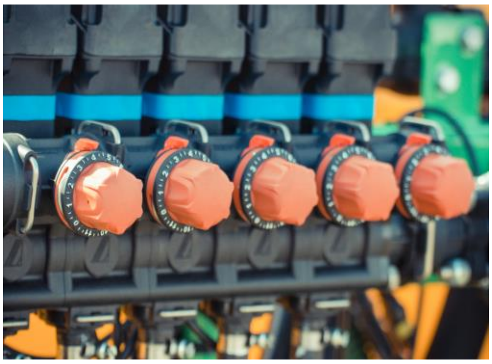
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 8 – Potentiometer

A potentiometer is an adjustable resistor used to create a variable voltage signal, typically between 0 and 10 V. In PLC systems, it's commonly used to set speeds, adjust levels, or simulate sensor values. Understanding how potentiometers work helps engineers control analogue inputs, scale values, and test system responses accurately.



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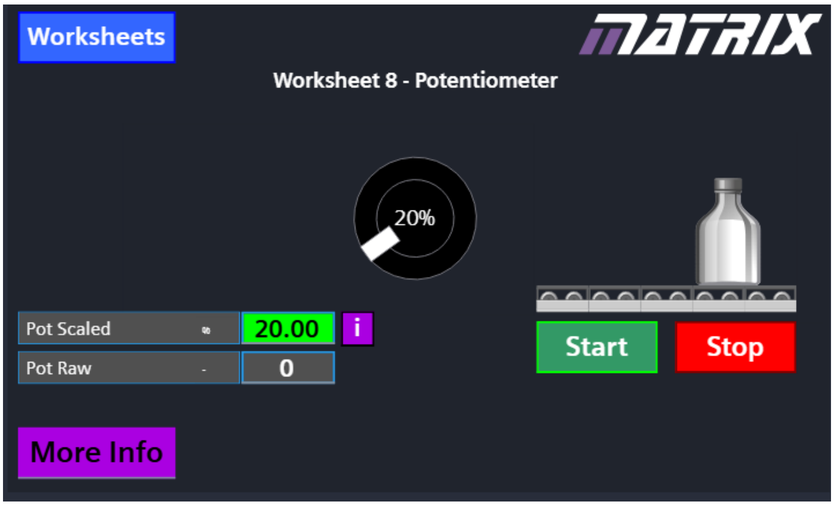


1. Navigate to worksheet 8 on the HMI.
2. Turn the potentiometer on your training rig down to 0 and observe the motor speed.
3. Slowly spin the potentiometer to the right, until the HMI screen shows 100%.
    - The motor should now be at full speed.
4. Click on the purple ‘i’ button next to the Potentiometer Scaled value.
5. In the new popup window, apply an offset of 50.
6. Now spin the potentiometer all the way to the 0 zero, fully left.
    - Observe what happens to the motor now as you spin the potentiometer.
7. Add an offset of -50 and repeat.
8. Remove the offset and now adjust the scalar value, change it from 100 to 10.

Worksheets

So What?

In industry, potentiometers are used to give operators direct control over speed, pressure, temperature or position. You'll find them on HMIs, control panels and test benches. Understanding how a potentiometer affects system response, especially how offsets and scaling change input behaviour, is critical when tuning systems or troubleshooting performance. If you don't understand how these settings impact the PLC's logic, you could misdiagnose a fault or incorrectly adjust a system. Real systems rarely use the full 0 to 10 V range, so knowing how to calibrate inputs in software is essential for reliable control.

This is an analogue input, meaning it sends a continuous voltage signal, usually between 0 and 10 V, to the PLC. To interpret this signal correctly, the PLC applies:

- **Offset:** Adds or subtracts a fixed number to the raw input.
  Example: A 2 V input with a +1 offset becomes 3 V.
  Useful for shifting the entire signal range up or down to correct for sensor drift.

- **Scalar:** Multiplies the input to stretch or compress the range.
  Example: A 5 V input with a scalar of 10 becomes 50 (5 × 10).
  This is how a 0–10 V input can be scaled to 0–100% or 0–1000 RPM.

These adjustments allow you to match the raw input signal to the real-world values your system needs.

Key Takeaways

- Potentiometers send a 0–10 V signal to the PLC's analogue input.
- The PLC uses this signal to control motor speed via PWM logic.
- Offset shifts the input up or down to adjust the control range.
- Scalar scales the input to match real-world values.
- Correct scaling is key for accurate system behaviour.

Student Handbook

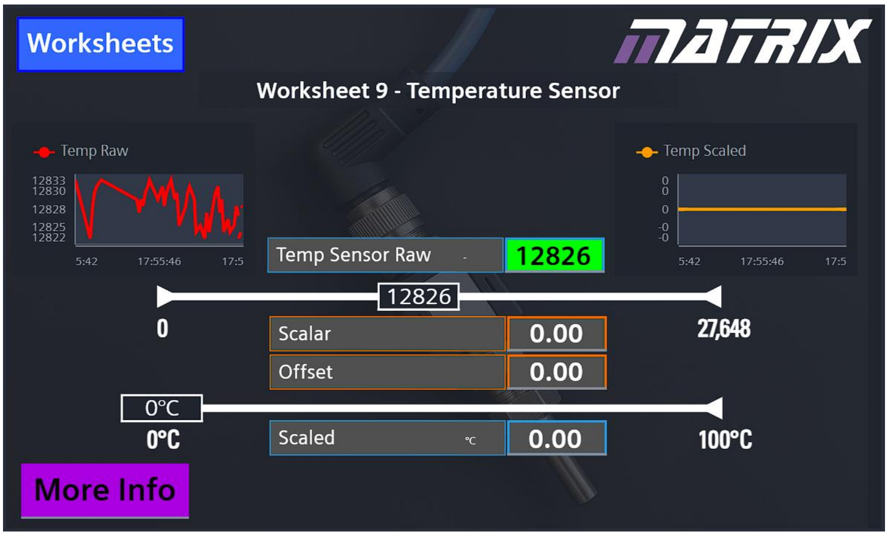
Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 9 – Temperature Sensor

A temperature sensor tracks heat levels in real time to maintain safe and efficient system operation. Common in automation and process control, it helps prevent overheating or freezing. Engineers must understand these sensors to detect faults, ensure accurate readings, and avoid equipment damage or shutdowns.

Over To You



1. Navigate to worksheet 9 on the HMI.
2. Place your fingers on the temperature probe on your training rig and observe how the “Temp Sensor Raw” value changes.
3. Remove your fingers from the probe and add a scalar value of 10 by clicking on the “0.00” of the orange scalar box.
    - Observe how the blue scaled value changes
4. Add a scalar value of 10 by clicking on the “0.00” of the orange scalar box.
    - Observe how the blue scaled value changes
5. Add a scalar value of 1000
    - Observe how the blue scaled value should now be much higher
6. Adjust the scalar value until you get to a sensible ambient temperature value (20-40°C).
    - You can find the correct scalar value in the IO Screen of the Main Menu.

Temperature sensors keep equipment safe by preventing overheating and detecting faults.

Types of Temperature Sensors:

- Thermocouple – Measures temperature by detecting voltage changes.
- RTD – Measures temperature through changes in resistance.
- Thermistor – A resistor that changes with temperature and responds quickly.

We are using a PT100 sensor probe, attached to an electronic IFM evaluation unit. This converts the resistance from the RTD into a 0-10V analogue voltage signal, that the PLC reads.

The PLC can't read resistance directly, but it can easily read voltage. So this conversion lets the PLC monitor temperature using one of its analogue input channels.

In Siemens PLCs, a 0–10 V analogue input is typically converted into a raw digital value ranging from 0 to 27,648.

- 0 V = 0
- 10 V = 27,648

This raw value is then scaled in your PLC program (using a scalar) to give a real-world value, like temperature.

$$\text{Scaled Value} = \text{Raw Value} \times \text{Scalar}$$

Voltage	Raw Value	Scaled Temp (°C)
0 V	0	0 × 0.0055 = 0 °C
2.5 V	6,912	6,912 × 0.0055 ≈ 38 °C
5 V	13,824	13,824 × 0.0055 ≈ 76 °C
7.5 V	20,736	20,736 × 0.0055 ≈ 114 °C
10 V	27,648	27,648 × 0.0055 ≈ 152 °C

If your PLC reads around 32,000, it's a fault. The maximum valid value is 27,648, so this usually means the sensor is disconnected, the voltage is too high, the input type is wrong, or there's a cable issue.

Key Takeaways

- A PT100 sensor measures temperature by changing resistance, which is converted into a 0–10 V signal for the PLC.
- The PLC reads this voltage as a raw value from 0 to 27,648, which must be scaled to display actual temperature.
- The scalar multiplies the raw value to produce a usable temperature reading in °C.
- A reading near 32,000 indicates a fault, like a disconnected sensor or wiring issue.
- Accurate scaling is essential to reflect real ambient temperatures, typically 20–40 °C in a classroom.

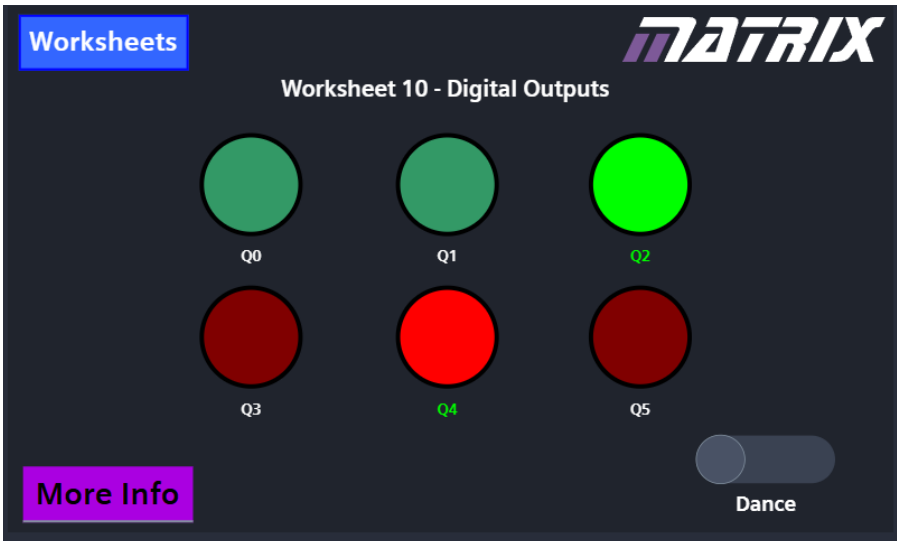
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheet 10 – Digital Outputs

Digital outputs are how a PLC controls external devices. These could be lights, motors, relays or solenoids. In this worksheet, you'll test a variety of output devices using buttons, sensors, and the HMI. This helps you understand how PLCs activate real-world hardware in response to logic conditions.

Over To You



1. Navigate to worksheet 10 on the HMI.
2. Press and hold the green push button I0.
   - Observe LED Q0 turn on only while the button is pressed.
3. Press the black button I1 once, making sure to release it.
   - Observe Q1 stay on even after releasing the button.
   - Press the red button I2 to turn it off.
4. Press the white latching button.
   - Observe LED Q2 turn on and stay on.
5. Turn the selector switch I4/I5 to the left, this will turn on input I4.
   - Observe the LED Q3 stay on.
6. Turn the selector switch I4/I5 to the right (turning on I5).
   - Observe the LED Q3 begin to flash.
7. Trigger the Proximity Sensor on and off

- Observe how the LED Q4 reacts

8. Spin the potentiometer AI0 slowly.
    - Observe the LED Q5 react to the position of the potentiometer dial.
9. Put all the inputs back to their original off state
    - You’ll need to press the red button I2 to turn off Q1
10. On the HMI, press the "Dance Mode" button.
    - Observe all 6 LEDs flash in a timed pattern or sequence.

So What?

As a maintenance apprentice, understanding digital outputs and how they operate is essential. This worksheet demonstrated that digital outputs can be triggered in many different ways; through buttons, switches, sensors, or even automated sequences from the PLC and HMI.

In industry, outputs are what actually make things happen: starting motors, energising relays, activating solenoids, opening valves, or turning on indicator lamps. Learning to recognise output sequences is especially valuable because real industrial processes rely heavily on precisely timed events.

The “LED dance” might seem gimmicky, but real industrial systems often sequence valves and actuators in timed patterns just like this. Whether it's a conveyor diverter or a safety purge cycle, these principles apply across all kinds of machinery.

With this new understanding, you'll be better prepared to:

- Identify correct or incorrect equipment behaviour by observing output patterns.
- Diagnose faults by tracing output conditions back to the PLC logic.
- Confidently troubleshoot and correct problems with actuators, valves, motors, and indicator systems.
- Recognise typical output sequences, helping you quickly pinpoint maintenance issues or confirm normal operation.

In short, your ability to interpret and understand digital outputs and their sequencing will significantly boost your effectiveness in industrial maintenance environments.

Key Takeaways

- PLCs use digital outputs to control devices like lights, motors, and valves.
- Outputs can be triggered by buttons, switches, sensors, or analogue signals.
- Latching and selector switches show different ways outputs behave.
- Proximity sensors and potentiometers affect outputs based on detection or position.
- HMI "Dance Mode" simulates real-world output sequences.
- Recognising output patterns helps with fault finding and system checks.

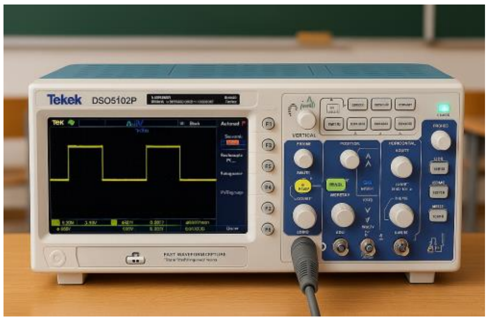
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 11 – Motor PWM

Pulse Width Modulation (PWM) is a method used by PLCs to control motor speed by rapidly switching an output on and off. The ratio of on-time to off-time determines how much power the motor receives. This worksheet explores how PWM is used to vary the speed of a DC motor.



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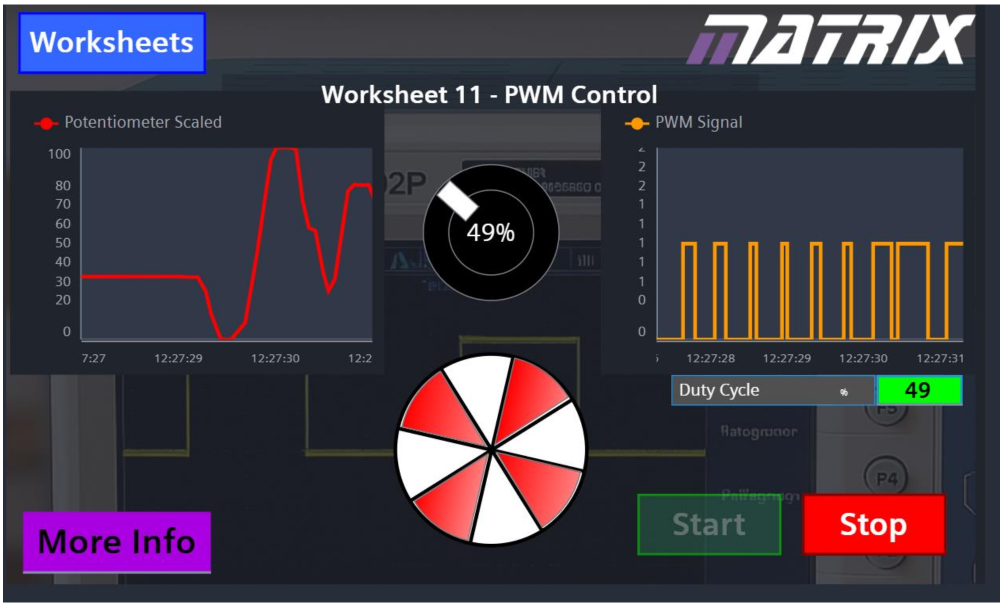


1. Navigate to worksheet 11 on the HMI.
2. Set the potentiometer to 0 (rotate anticlockwise).
3. Start the program with the green start button.
4. Rotate the potentiometer clockwise.
    - Observe how the motor speed increases as you rotate.
5. Rotate the potentiometer from 100% to 0% a few times.
    - Observe how the Potentiometer Scaled value is graphed on the left.
    - Observe how the PWM Duty Cycle is displayed on the right.

Worksheets

So What?

You’ll come across motors everywhere in industry: fans, pumps, conveyors. They don’t always just run at full speed. That’s where PWM comes in. It’s how PLCs can vary motor speed without needing complex analogue output modules.

In real systems, a PLC uses PWM to control things like fan speed in HVAC systems, mixing rates in food production, or even soft-starting a conveyor belt. You need to understand that the duty cycle directly affects motor performance. 100% means fully on, 0% means off, and anything in between gives variable speed.

Reading the HMI helps you see what the PLC is doing, but more importantly, tracing how your input (the potentiometer) affects the output (the motor) builds your core diagnostic skills.

In the field, you'll be expected to:

- Scale and interpret analogue inputs
- Monitor PWM signals in software
- Fault-find speed control issues from the HMI or field wiring

This exercise shows you that controlling a motor isn’t just about wiring it up. It’s about understanding how software, inputs, and outputs all work together. That's what industrial automation is all about.

Key Takeaways

- PWM controls motor speed by switching outputs on and off quickly.
- Duty cycle (%) affects how fast the motor runs.
- The potentiometer sets the PWM level via a 0–10 V input.
- The HMI shows both the input value and PWM output.
- PWM is used in fans, pumps, and conveyors for speed control.
- Knowing how to read and scale PWM is vital for diagnostics.

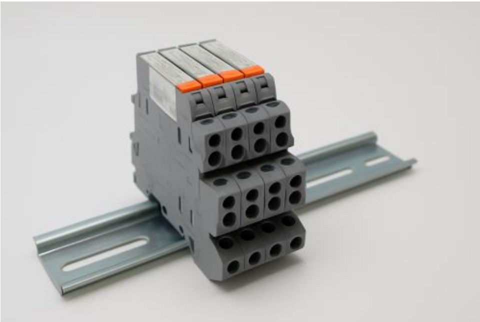
Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

Worksheets

Worksheet 12 – Relays

Relays are electrically operated switches that allow a PLC to control higher-power devices safely. The PLC energises a low-power coil, which activates internal contacts to switch outputs on or off. This worksheet helps you understand how relays isolate and control output devices like motors or solenoids.



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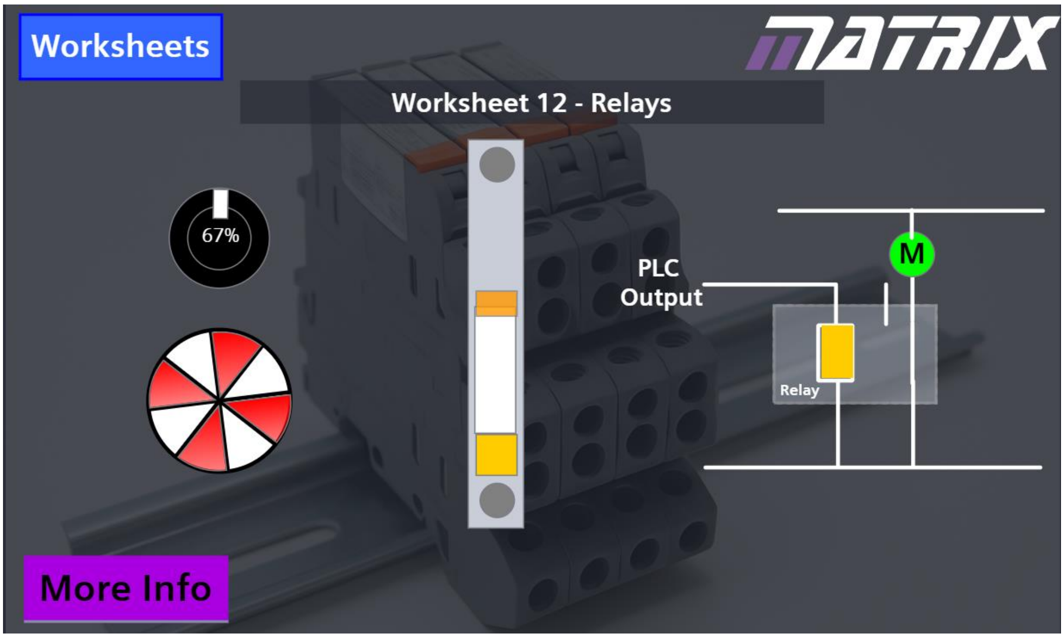

1. Navigate to Worksheet 12 on the HMI.
2. Press the green I0 button to fire the relay.
    a. Observe the relay LED turn on when the PLC energises the relay coil.
3. Press the red button I2.
4. Confirm the relay switches off and the output device stops.
5. Turn the potentiometer slowly.
    a. At about 50%, the relay should activate automatically.
6. Observe the output LED or motor. It will only run when the relay is energised.
7. Press the emergency stop and check that the relay deactivates.

So What?

In real systems, PLC outputs can’t always drive motors or solenoids directly. Relays act as the bridge between low-power control and high-power loads. You’ll often find relays switching lighting, heaters, or valves.

Knowing how to test and trace relay wiring is essential. You’ll need to diagnose issues like stuck contacts, faulty coils, or incorrect logic. This worksheet shows how the PLC controls the relay and how the relay controls the load, a key concept in industrial automation.

Key Takeaways

- Relays allow PLCs to control higher-power devices like motors and solenoids.
- The PLC energises a coil, which closes internal contacts to switch the load.
- Relays provide **electrical isolation** between the PLC and output devices.
- You can observe relay status via LEDs on the relay and HMI.
- Relays are essential for safely switching outputs in most industrial systems.
- Understanding how to trace relay circuits is key for troubleshooting.

Student Handbook

Complete The Questions & Answers in the Student Handbook relating to this worksheet.

STUDENT HANDBOOK

Questions:

1. What type of control does this system demonstrate?

___

___

2. What happens when you press and hold input I0?

___

___

3. What do the PLC's status LEDs show during operation?

___

___

4. Where might a system like this be used in real industrial settings?

___

___

Worksheet 2 – Complex PLC Systems

Questions:

1. What does a complex PLC system control?

2. What happens when you press input I0 in this worksheet?

3. What does it mean when the PLC latches a signal?

4. How can the process be stopped once it starts?

5. Why is understanding PLC logic important for fault finding?

Worksheet 3 – HMIs

Questions:

1. What is the purpose of an HMI in an industrial system?

____

____

2. What does this worksheet's HMI screen represent?

____

____

3. What happens when you press the Mix button?

____

____

4. Why are some HMI controls greyed out during mixing?

____

____

5. How can maintenance engineers use HMIs during fault finding?

____

____

Worksheet 4 – Emergency Stop

Questions:

1. What is the purpose of an Emergency Stop (E-Stop)?

____

____

2. How is an E-Stop different from a normal stop button?

____

____

3. What happens when you press the E-Stop during the mixing process?

____

____

4. Why does the E-Stop have two contacts?

____

____

5. What steps must be taken to reset the system after pressing the E-Stop?

____

____

Questions:

1. What is the purpose of the status LED in a PLC system?

2. What does a red status LED usually mean?

3. What does a green status LED usually mean?

4. How does the status LED change across Basic, Enhanced, and Live Process modes?

5. Why is it important to understand how the LED is programmed?

Worksheet 6 – Normally Open vs Normally Closed

Questions:

1. What is the difference between a normally open (NO) and normally closed (NC) contact?

___

___

2. What does green text on the HMI input screen mean?

___

___

3. How does Input 2 behave when not pressed?

___

___

4. What happens to Input 3 when it is pressed and released?

___

___

5. Why is it important to understand NO and NC input states in maintenance?

___

___

Questions:

1. What does a proximity sensor detect?

2. Why are proximity sensors useful in automation systems?

3. What type of object does an inductive sensor detect?

4. What caused the fault in the locking sequence during the exercise?

5. How can engineers test a proximity sensor during troubleshooting?

Worksheet 8 – Potentiometer

Questions:

1. What does a potentiometer do in a PLC system?

2. What voltage range does a potentiometer typically output?

3. How does the motor respond as you turn the potentiometer?

4. What does applying an offset do to the input signal?

5. Why is scaling (scalar) important in PLC systems?

Worksheet 9 – Temperature Sensor

Questions:

1. What does a temperature sensor do in a PLC system?

___

___

2. What type of temperature sensor is used in this worksheet?

___

___

3. Why is a signal converter needed with an RTD sensor?

___

___

4. What does the PLC do with the analogue voltage from the sensor?

___

___

5. What might a raw value near 32,000 mean?

___

___

Questions:

1. What are digital outputs used for in a PLC system?

____

____

2. What happens when you press and hold input I0?

____

____

3. How does input I1 behave differently from I0?

____

____

4. What does the selector switch (I4/I5) control in this worksheet?

____

____

5. Why is it useful to recognise output patterns like the LED sequence?

____

____

Questions:

1. What does PWM stand for, and what is it used for in PLC systems?

2. How does PWM control the speed of a motor?

3. What role does the potentiometer play in this worksheet?

4. What does a 100% duty cycle mean compared to 0%?

5. Why is it important to understand PWM when working with motors?

Worksheet 12 – Relays

Questions:

1. What is the main purpose of a relay in a PLC system?

2. How does the PLC activate a relay?

3. What happens when the relay is energised?

4. Why can’t PLCs always control devices like motors directly?

5. What should you check if a relay does not switch as expected?

Safety Note

SAFETY NOTE

As you step into the world of industrial maintenance, **safety must always come first**. Every machine, tool, and system you work with has risks, but following the right procedures keeps you and your team safe.

There are official safety standards and regulations, like the **Machinery Directive 2006/42/EC**, that exist to ensure all maintenance work is carried out correctly and safely. In the **EU** there is the **EN 60204-1** (electrical safety for machinery) and in the **US**, **OSHA 1910** (general industry safety) and **NFPA 70E** (electrical safety for workers). These standards help maintenance engineers work safely, reduce risks, and comply with legal requirements. Once you get into Industry, get a copy of these and learn them. They may save your life. The best engineers aren't just good at fixing machines; they're smart enough to work safely.

1. Lock It Out, Stay Safe

Before you touch any machine, make sure it's isolated from power. Use Lockout/Tagout (LOTO) procedures to lock off energy sources (electricity, hydraulics, pneumatics). Machines can start unexpectedly, so always check before working.

2. Read the Manual, Know the Rules

Every machine has a manufacturer's manual it's there for a reason. Read it. Follow it. Never assume you know how something works without checking first.

3. Wear the Right Gear

Your Personal Protective Equipment (PPE) isn't optional. Safety glasses, gloves, boots, and hearing protection help prevent injuries that could end your career before it starts.

4. Only Work on What You Understand

If you're unsure about something, ask. Rushing in without the right knowledge can be dangerous. Learning the correct procedures now will make you a better and safer engineer in the long run.

Safety Note

5. Keep Your Workspace Clear

Slips, trips, and falls are some of the most common accidents in maintenance. Keep tools, cables, and waste tidy to prevent hazards.

6. Electrical Safety is No Joke

Always turn off and test before working on electrical systems. Use insulated tools and check grounding a bad connection can be deadly.

7. Moving Parts Can Kill

Machines have stored energy, even when turned off. Always block, chock, or brace moving parts before working on them. Never assume something is safe just because it's not running.

8. Watch Out for Pressure

Hydraulics and pneumatics store energy in pipes, hoses, and tanks.

- Always depressurize systems before working on them.
- Inspect hoses and fittings for leaks never use your hands to check, use cardboard instead.
- A burst hose can cause serious injuries look for signs of wear before starting work.

9. Be Ready for Emergencies

Know where emergency stops, fire extinguishers, and first aid stations are. If something goes wrong, you need to act fast and correctly.

10. Speak Up About Faults

If you find something wrong don't ignore it. Report faults immediately, and don't use unsafe equipment. A quick fix now could prevent a serious accident later.

VERSION CONTROL

11 07 25	First Revision Created