MATRIX | INDUSTRIAL MAINTENANCE

PLC Fundamentals Trainer
User Manual

MATRIX

IM6930

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Introduction

INTRODUCTION

This manual supports tutors, technicians, and students in the safe and effective use of the PLC Fundamentals Trainer. The system provides a hands-on learning experience in PLC-controlled automation using a Siemens S7-1214 PLC and a Unified Basic HMI. Users will explore real industrial components including sensors, motors, relays, and safety circuits. Activities include I/O testing, relay logic, PWM motor control, and fault diagnostics. The content supports key outcomes from T Level Engineering & Manufacturing qualifications (8712 / 8713).

Intended Audience

- College and university students aged 16+ studying engineering, automation, or industrial maintenance
- Apprentices beginning careers in PLC systems, mechatronics, or control panel wiring
- Instructors and technicians delivering vocational training or maintaining teaching equipment

SAFETY INFORMATION

Read this section before operating the system. Failure to follow safety guidance may result in injury or equipment damage.

Electrical Equipment Caution	
24 V DC – disconnect power before opening or servicing. **Symbol:** ISO 7010 W012 – Risk of electric shock	
Moving Parts Warning	
The motors on this system drive rotating components. Keep hands, hair, and loose clothing away from moving parts during operation. **Symbol:** ISO 7010 W001 – General warning	
Emergency Stop Instruction	
Push to stop. Twist to release. Simulated function only – not safety-rated. **Symbol:** ISO 7010 E007 - Emergency Stop	
Disconnect Before Maintenance	
Disconnect power before accessing wiring or components. **Symbol**: ISO 7010 M002	

Safety Information

Residual risk statement

This product has been designed to minimise hazards as far as reasonably practicable (ALARP). The following residual risks remain:

- Rotating motor – the 24 V DC motors have rotating elements which may cause minor injury if touched during operation.
- Electrical exposure – although operating at 24 V DC, improper use may still pose risk.

Always keep the enclosure closed during operation and ensure users are supervised when in a learning environment.

Electrical safety

- Only use the supplied Class II (double insulated) 24 V DC power supply.
- Disconnect the PSU before performing any maintenance or inspection.
- Do not bypass the PLC by wiring the motors directly to 24 V. This may result in uncontrolled operation and thermal damage.
- Inspect power cables periodically for signs of damage or wear.

Mechanical and thermal safety

Unstable Placement

The unit is portable and bench-mounted. Dropping or tipping it can cause mechanical damage.

Pinch Points

Some mounted components (e.g., terminal blocks, motor brackets) may create small pinch points during handling or wiring.

Personal protective equipment (PPE)

- No PPE is required under normal use.

EMERGENCY PROCEDURES

This system is intended for educational use and does not include a hardware-certified emergency stop circuit. The E-Stop is implemented in software only, without a safety relay, and is not compliant with BS EN 60204-1. However, it still performs a simulated safety function for training purposes.

In the event of unsafe or unexpected system behaviour, follow the procedure below:

- Press the Emergency Stop button. This simulates a dual-channel fault in the PLC and immediately disables outputs.
- If the system does not respond, or remains active despite the E-Stop, immediately turn off the MCB on the front of the product and disconnect the 24 V DC power supply from the rear of the unit.
- Do not restart the system until the cause has been identified and addressed.
- Release the E-Stop by twisting clockwise, then press the Reset button before restarting.
- For issues that persist, check the Faults or IO screen for more information, or consult your instructor or technician.

Emergency Conditions Reference

Situation	Immediate Action	Reset Sequence
Emergency stop pressed	PLC disables outputs; status LED turns red	Twist E-Stop to release, press Reset, then press Start
Motor overheating	PLC shuts off motor output as a safety precaution	Allow to cool, then press Reset and Start
Fault condition triggered	Output is disabled; fault shown on HMI	Resolve issue, then press Reset on HMI
Wiring or short detected	System may shut down or MCB may trip	Isolate power, inspect connections, reset MCB, then power on

This table provides a quick summary of typical emergency events and how to respond safely. Always refer to the full procedures and safety notes before resuming operation.

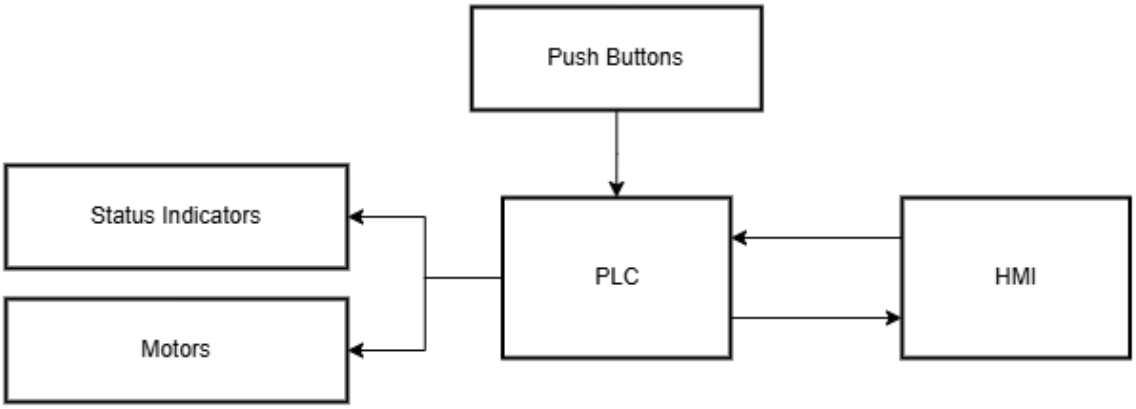
SYSTEM DESCRIPTION

Functional overview

The rig simulates an industrial control system using real-world components such as push buttons, sensors, relays, and motors. The Siemens PLC processes digital and analogue inputs to control outputs including indicator LEDs and variable-speed motors. Built-in simulated faults allow learners to practise diagnosis and troubleshooting in a realistic, hands-on environment.

Block diagram

The diagram illustrates how user inputs, sensor feedback, and actuator control interact within the PLC Fundamentals Trainer. The system is fully automated, using a Siemens S7-1200 PLC and Unified HMI to process inputs and control outputs such as indicator LEDs and motors in real time.



PROCESS OVERVIEW

HMI & Worksheets Access

Users begin by navigating to the Main Worksheets screen on the Unified HMI.

This screen features 12 clearly labelled buttons, each launching a dedicated worksheet.

Each worksheet teaches a different concept, such as digital inputs and outputs, emergency stop circuits, analogue signals, PWM control, or relay operation.

Screens are interactive, guiding learners through hands-on tasks with real-time system feedback.

PLC Control Logic

The Siemens S7-1200 PLC monitors input devices such as push buttons, proximity sensors, potentiometers, and temperature sensors.

Based on programmed logic and worksheet selection, the PLC activates relevant outputs.

Safety features like emergency stops and reset logic are integrated throughout the system.

Outputs & Actuators

Outputs include indicator LEDs, DIN rail-mounted relays, and 24 V DC motors with visual RPM feedback.

Digital outputs respond to input conditions, while analogue outputs simulate variable control for learning purposes.

Motor speed and LED states provide visual cues to support understanding of PLC actions.

Sensor Feedback & Input Response

Real-time inputs are processed by the PLC and reflected instantly on the HMI.

Process Overview

Key components

This training rig is built using real industrial-grade components to give students and engineers hands-on experience in PLC wiring, sensor interfacing, output control, and basic fault diagnosis.

Each component has been carefully selected to reflect UK industry standards, helping learners build confidence with hardware they are likely to encounter in real-world maintenance and automation environments.

The following section outlines the purpose and capabilities of the core components used in the rig.

PLC – Siemens S7-1200 (CPU 1214C)
• **Purpose:** Central controller for logic, worksheet control, safety interlocks, and I/O processing
• **Key Features:**
  ○ 14x Digital Inputs, 10x Digital Outputs (24VDC)
  ○ 2x Analog Inputs (0–10V)
  ○ Handles all worksheet programs.
  ○ Interfaces with HMI for controls, alarms, and diagnostics
	

Unified HMI – Siemens Unified Basic Panel (MTP700)
• **Purpose:** Operator interface for real-time monitoring, fault display, and parameter input
• **Key Features:**
  ○ 7" touch screen for inputs and system feedback
  ○ Displays alarms, I/O status, values, and temperature cutoffs.
  ○ Setup page allows editing of temperature cutout limits and viewing system state
	

Process Overview

Proximity Sensor – Omron E2E-X16MB1T12 (Inductive, M12, PNP, NO)
• **Purpose:** Detects the presence of nearby metal objects without physical contact, simulating object detection and position sensing in industrial systems.
• **Key Features:**
  ○ Inductive sensing with a 16 mm detection range
  ○ PNP normally open output, ideal for PLC digital input testing
  ○ Integrated status LED for visual confirmation of target detection
  ○ Used in worksheets to demonstrate object detection, logic response, and fault simulation
	

Temperature Sensor – IFM TM4101 (PT100 RTD, 4-Wire)
• Purpose: Measures temperature by detecting resistance changes in a platinum element, providing accurate thermal data for analogue signal processing.
• **Key Features:**
  ○ PT100 Class B RTD with 4-wire connection for high accuracy
  ○ Stainless steel probe, 6 mm diameter, suitable for panel integration
  ○ Operating range up to +150 °C, ideal for safe training environments
  ○ Used to demonstrate analogue input scaling, temperature monitoring, and sensor calibration
	

Process Overview

Temperature Transmitter – IFM TP9237 (Evaluation Unit for PT100/PT1000)

- Purpose: Converts the resistance signal from a PT100 or PT1000 sensor into a standard 0–10 V analogue output readable by the PLC.
- **Key Features:**
  - Compatible with PT100 and PT1000 sensors
  - Outputs a 0–10 V signal for PLC analogue input channels
  - Industrial-grade design with secure terminal connections
  - Enables learners to explore voltage scaling, analogue signal interpretation, and fault diagnosis

TECHNICAL SPECIFICATIONS

The system is designed for safe, low-voltage use in training environments. Key electrical, mechanical, and environmental parameters are summarised below:

Parameter	Value
Supply voltage	24 V DC (via external double-insulated PSU)
Input current	1.5 A nominal, 2A peak
Power consumption	< 60 W
Fuse / MCB	3A type B MCB (Siemens 5SY4103-7)
Ingress protection	IP20 (training lab use)
Ambient temperature	5 °C … 35 °C
Noise emission	< 60 dB A at 1m
Overall dims (W×H×D)	520 × 435 × 461 mm
Mass	4 kg

Note: The rig operates at SELV levels only; no mains voltages are present inside or outside the enclosure.

STANDARDS & COMPLIANCE

This product has been designed and assembled in accordance with the following UK and EU standards and directives to ensure electrical safety, electromagnetic compatibility, and suitability for use in educational and training environments:

BS EN 60204-1:2018 – Safety of machinery – Electrical equipment of machines

The system uses 24 V DC SELV switchgear, with compliant control wiring, labelled terminals, and a dual-channel emergency stop circuit in line with Clause 9.2.2.

> Note: While the E-Stop is dual-channel, it is not monitored by a safety-rated relay and does not remove power directly from actuators. The E-Stop functionality is processed in software via standard PLC inputs. This means the system does not meet full functional safety requirements (e.g. Performance Level d or Category 3). As such, it is not compliant for industrial machinery under the Machinery Directive but is considered acceptable for controlled educational use. A risk assessment and signage are provided to communicate this limitation.

BS 7671 (IET Wiring Regulations) – Requirements for Electrical Installations
All circuits operate below 50 V AC / 120 V DC, classifying the system under Safety Extra-Low Voltage (SELV). This eliminates the need for protective earthing and reduces electrical risk in an open-access training setting.

Low Voltage Directive (2014/35/EU)
Applies only to the external 24 V DC power supply unit, which is CE-marked and tested under EN 62368-1 for IT and AV equipment.

EMC Directive (2014/30/EU)
The system has been evaluated for electromagnetic compatibility and complies with:

EN 61000-6-1 / EN 61000-6-2 – Immunity for industrial environments

EN 61000-6-3 – Emissions for light industrial environments

Standards & Compliance

Machinery Directive (2006/42/EC)

This product is classified as partly completed machinery. It includes built-in safeguards, clear instructions, and a supporting risk assessment. The system is not suitable for unsupervised or production use and must be operated in a supervised training environment.

A formal UKCA / CE Declaration of Conformity is provided in Appendix D, along with supporting documentation covering electrical design, safety considerations, and component certifications.

DESCRIPTION OF COMPONENTS

This section describes all major components used in the training rig, organised into functional categories. Each item plays a distinct role in delivering safe, accurate, and realistic closed-loop control behaviour. Where relevant, drawing references are provided to aid in system understanding, maintenance, and fault-finding.

The categories are as follows:

- **Control Hardware**: The programmable logic controller (PLC) and HMI used for automation and user interface.
- **Safety Devices**: Components designed to detect unsafe conditions and shut down the system accordingly.
- **Operator Controls**: Push buttons and user input devices used to reset or manage system operation.
- **Indicators**: Visual indicators that show system state (e.g. running, faulted, or in E-Stop).
- **Actuators:** Output devices such as motors, LEDs, and relays that respond to PLC commands and provide visible or mechanical feedback.
- **Sensors:** Input devices including push buttons, proximity sensors, potentiometers, and temperature sensors that send real-time signals to the PLC.
- **Power & Protection**: Electrical supply and protective devices ensuring the system operates within safe parameters.

Each item listed in this section includes a short description of its function within the system, the signal type it uses (if applicable), and how it interacts with the PLC and HMI. These components form the foundation for both the control logic and the training experience.

Description of Components

Control Hardware

Siemens S7-1200 PLC

Part Number: S7-1214C
Manufacturer: Siemens
Drawing Reference: PLC1

The Siemens S7-1214 is an industrial-grade Programmable Logic Controller (PLC) and serves as the central control unit of the training system. It processes real-time logic, manages all digital and analogue I/O, and interacts directly with the Unified HMI. In this training rig, it is responsible for:

- Monitoring digital and analogue inputs such as push buttons, potentiometers, proximity sensors, and temperature signals
- Controlling outputs including indicator LEDs, relays, and 24 V DC motors
- Executing logic for tasks like PWM motor control, interlocks, and signal sequencing
- Handling safety logic including emergency stop and reset functionality
- Responding to fault simulations for training in diagnostics and troubleshooting
- Communicating with the Unified Basic HMI over internal Ethernet for real-time status display and interaction

The S7-1214 supports expansion through additional I/O or communication modules, offering flexibility for future development or customization.

Siemens Unified HMI – 7" Touch Panel

Part Number: MTP700 Unified Basic
Manufacturer: Siemens
Drawing Reference: HMI1

The Human-Machine Interface (HMI) provides an intuitive touchscreen for students and operators to monitor system status and interact with the training rig.

- Live visualisation of inputs and outputs using clear I/O status indicators and mimic diagrams
- Fault and alarm pages that display real-time system errors with timestamps

- Setup menus for adjusting scalar and offset values for analogue inputs such as the potentiometer and temperature sensor
- Start, stop, and reset controls for safe interaction and fault recovery
- A consistent, easy-to-navigate layout designed for clarity and effective learning, following high-performance HMI design principles

The HMI is connected directly to the PLC over Ethernet and uses the Siemens Unified Runtime environment.

Safety Devices

Emergency Stop

Drawing Reference: S6-S7

The emergency stop is a dual-channel, latching pushbutton assembly designed to safely shut down the system in the event of an emergency. It consists of:

- A large 40 mm red mushroom-head actuator, which is twist-release to reset.
- A yellow backing plate, providing visual compliance with machinery safety standards.
- Two normally closed (NC) contact modules, wired separately into the PLC for dual-channel monitoring, allowing detection of mechanical or wiring faults.

When activated, the E-Stop immediately stops system operation and triggers a safety fault condition shown on the HMI and status light. The system remains locked out until the E-Stop is released and the reset button is pressed.

> Note: While this system simulates dual-channel E-Stop behaviour in software, it does not include a safety relay and does not fully meet the requirements of BS EN 60204-1 for industrial deployment. See the Safety section for details.

Description of Components

Operator Controls

Reset Button

Drawing Reference: S8

- Blue illuminated plastic push button (momentary)
- **Function:** Used to reset system faults and re-enable operation after an E-Stop or error

Indicators

Indicator – Multi-Colour LED Beacon

Model: Banner K50LGRYPQ
Type: Sealed RGB LED indicator beacon (not stack light)
Voltage: 18–30 V DC
Protection Rating: IP67 / IP69
Mounting: Base mount, M30 thread

This compact, high-visibility LED beacon provides clear indication of system status via full-surface colour changes:

- **Green** – System operating normally
- **Yellow** – Fault detected
- **Red** – Safety stop or E-Stop triggered

Unlike traditional stack lights, this unit shows status via a single lens that changes colour. It is IP-rated for harsh environments, making it ideal for workshop and classroom conditions where visibility and robustness are critical.

Description of Components

Actuators

The PLC Fundamentals Trainer features a range of output devices (actuators) that respond to PLC commands and provide visible or functional feedback. These include:

- **Indicator LEDs:** Red and green LEDs illuminate based on PLC digital outputs, providing instant visual confirmation of system states and logic conditions.
- **24 V DC Motors:** Two geared motors with RPM discs visually demonstrate output activation and PWM speed control. They are ideal for showing variable speed and directional control.
- **DIN Rail-Mounted Relays:** Electromechanical interface relays isolate PLC outputs from load circuits. When energised by the PLC, they switch outputs such as motors or lamps, demonstrating safe industrial switching.

These actuators are wired to the Siemens S7-1214 PLC and are controlled via HMI interactions or physical input devices. They help learners observe how outputs behave in response to logic, safety states, and analogue signal changes.

Sensors

These components provide live system data to the PLC, enabling accurate closed-loop control, interlocks, and fault handling.

PT100 RTD Temperature Sensor with Transmitter

Drawing Reference: TH1
A precision temperature probe used to monitor the ambient temperature. It is paired with a 4–20 mA transmitter for robust signal delivery to the PLC.

- Accurate thermal feedback for process protection
- Used in over-temperature and under-temperature shutdown logic
- Configurable cut-out thresholds via HMI

Inductive Proximity Sensor

Drawing Reference: PX1
Detects metal using non-contact metal sensing. Used in worksheets.

Description of Components

- Interlock to prevent operation with open lid
- Flicker mode used to simulate intermittent sensor faults
- Status shown on IO page and used in safety logic

Power & Protection

24 V DC Power Supply (Class II Isolated)

Drawing Reference: PSU1

Converts mains input to a **safe SELV 24 V DC output** for all system components.

- CE/UKCA marked
- Double-insulated (no protective earth required)
- Plug-in barrel connector simplifies setup

3A Miniature Circuit Breaker (Type B, 1P)

Drawing Reference: MCB1

Protects the low-voltage circuit from overcurrent and short circuits.

- Fast tripping on fault detection
- Mounted in rear panel and labelled for isolation
- Compliant with BS EN 60898 and BS EN 60204-1

UNPACKING & INSTALLATION

1. Inspect packaging for transit damage.
2. Verify contents against packing list (Appendix B-1).
3. Place rig on a level bench; leave 100 mm clearance each side.
4. Connect **24 V DC > 2.5 A** supply to barrel jack (centre +).

COMMISSIONING / START-UP

Step	Action	Expected result
1	Turn on Circuit Breaker	HMI and PLC turns on
1	Release E-Stop & press **Reset**	Status light turns green
2	On HMI, press **Start**	Main Menu shows, all output LEDs turn on

Commissioning Advice

Inspect the Unit: Check for loose wires, damaged components, or unsecured terminals.

Power Setup: Use the supplied 24 V adapter. Ensure MCB is off before connecting, then power on.

HMI Check: Confirm touchscreen boots to main menu and responds to input.

PLC Status: Check PLC RUN LED is green. No fault LEDs should be active.

Normal Operation

NORMAL OPERATION

Startup Procedure

- Switch on the front-mounted MCB to power the system.
- Wait for the HMI and PLC to boot up. Navigate to the Worksheets screen.

Worksheet Selection

- Choose from 12 worksheet buttons on the HMI. Each worksheet activates a unique screen for a specific concept.

Using Inputs

- Operate buttons, selector switch, potentiometer, and sensors as instructed.
- Confirm input status via HMI indicators.

Observing Outputs

- Watch LEDs, relays, and motors activate in response to logic.
- Motor speed may vary depending on potentiometer or program state.

Emergency Stop Handling

- Press the emergency stop to disable outputs.
- Twist to release, then press the blue reset button or use the HMI reset to resume.

Shutdown Procedure

- When finished, switch off the front MCB to fully power down the unit.
- Disconnect power if transporting or storing.

HMI MANUAL

The Human-Machine Interface (HMI) provides a structured and user-friendly way to operate, monitor, and diagnose the system. It is divided into clearly labelled screens, accessible via the Main Menu, each serving a specific function.

This section of the manual explains the purpose and layout of each screen, including how to interact with system controls, view real-time data, respond to faults, and configure operating parameters.

The HMI consists of the following main screens:

- **Main Menu** – Central navigation point to access all other screens
- **Worksheets** – Provides access to 12 interactive training screens, each focused on a specific PLC concepts.
- **IO** – Displays raw input and output signals for monitoring and diagnostics
- **Faults** – Shows active software or hardware faults with logic status
- **Alarms** – Time-stamped alerts
- **Setup** – Configuration screen for limits, and cut-out thresholds

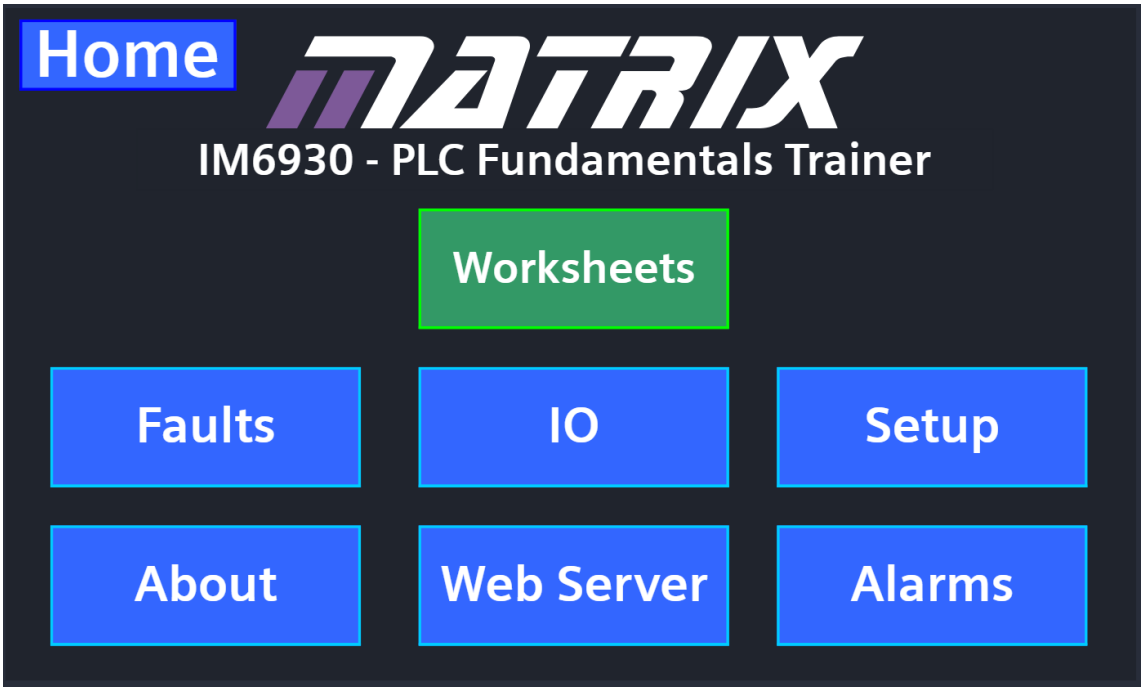
Each screen is designed for clarity and ease of use, supporting both normal operation and fault investigation workflows.

Start Screen

This is the screen that loads when the software starts.

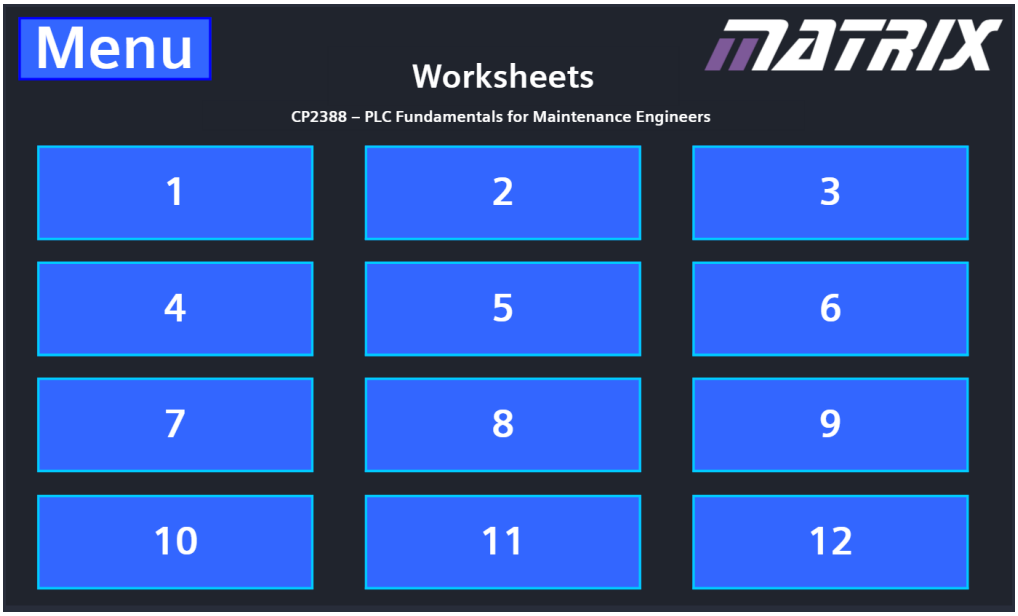
Main Menu Screen

It serves as the main navigation panel and all other screens have a “Menu” button in the top left corner that leads back to this screen.



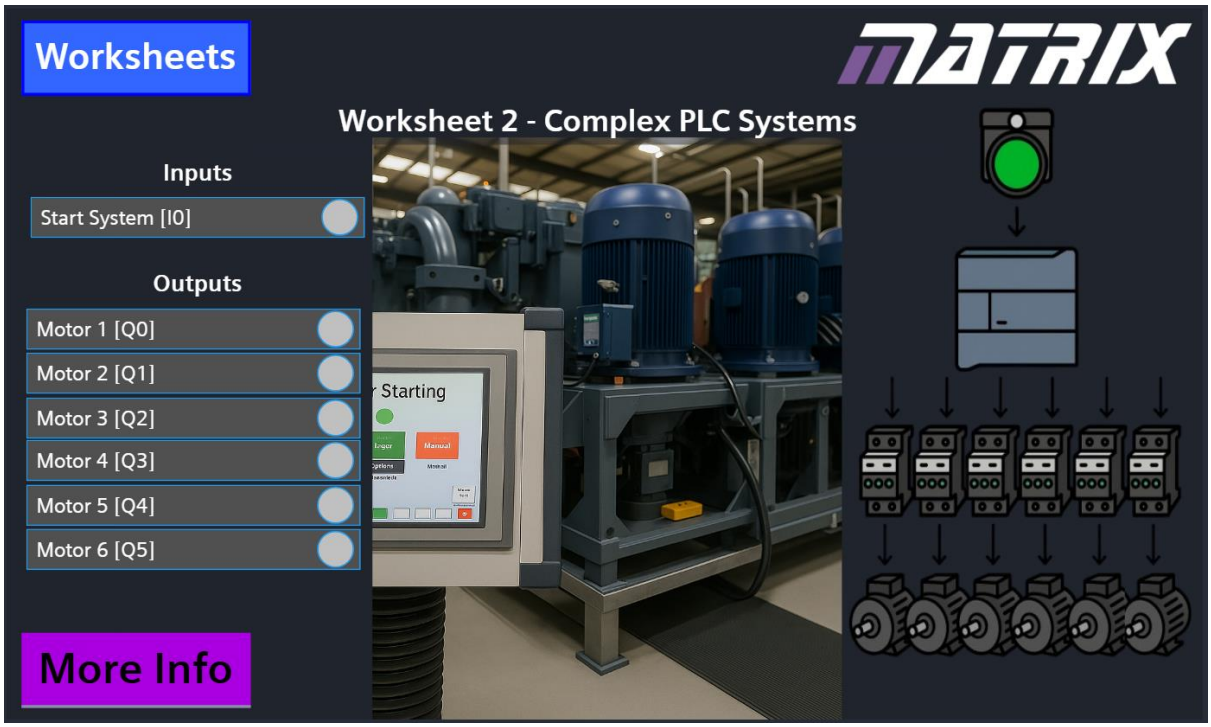
Starting The Program

You start the programs by pressing the “Worksheets” button on the main menu. This takes you to a screen with the 12 different worksheets.



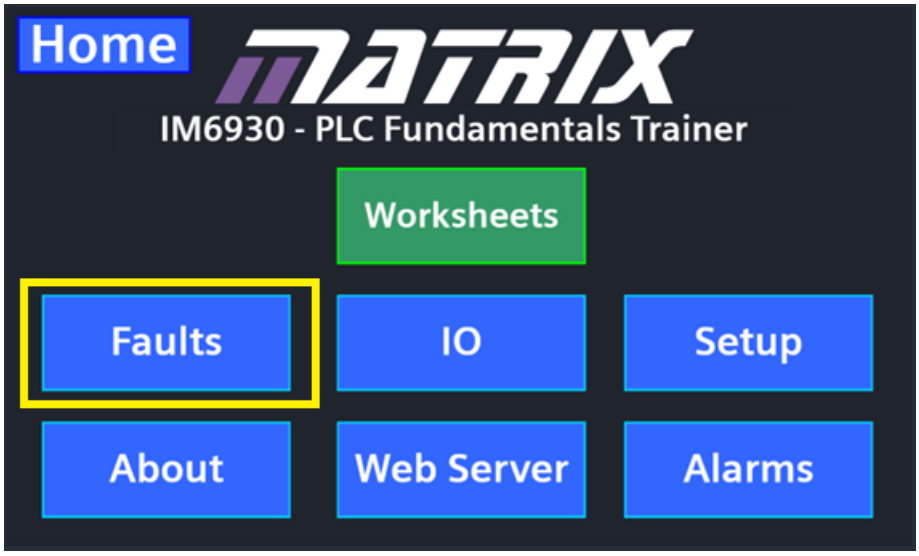
Example of Worksheet Screen

Here is an example of one of the worksheets, worksheet 2.



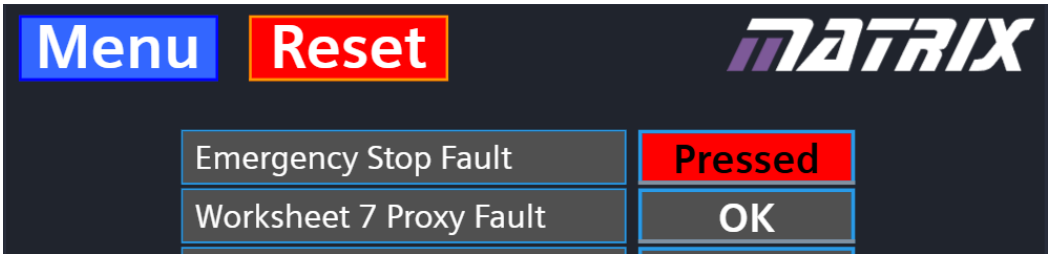
Faults

If abnormal behaviour is detected, consult the Faults page or IO screen for further diagnostics.

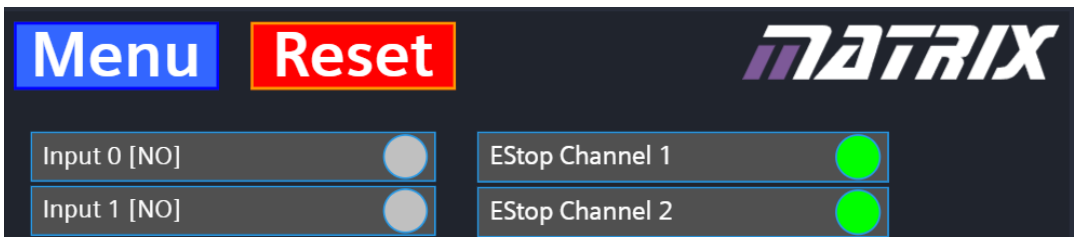


Example Fault – Emergency Stop

Should a fault occur, navigate to the Main Menu and then to the Faults page. This will show you active faults. If a fault is active it will show as “Active” and be highlighted red. All inactive faults will state either “OK” or “-“.



You can also use the IO screen to help assist in fault diagnosis. Navigate to the Main Menu, then IO screen. This shows the status of each input on the system.



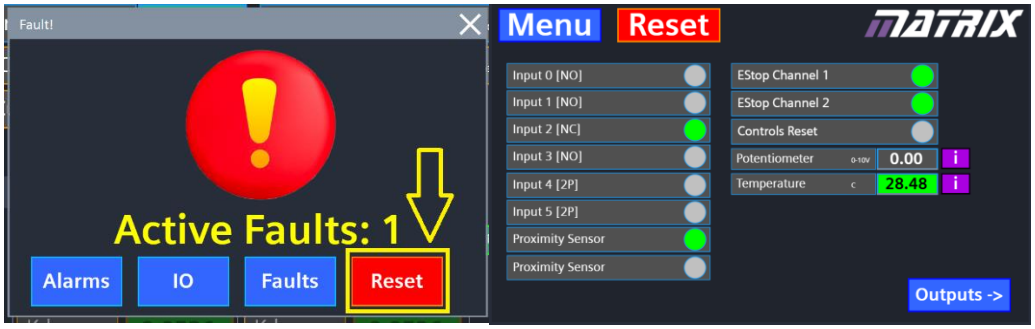
Safety Fault

If a safety fault occurs relating to the emergency stop, the system will shut down, and the beacon will flash red.

Fault Reset

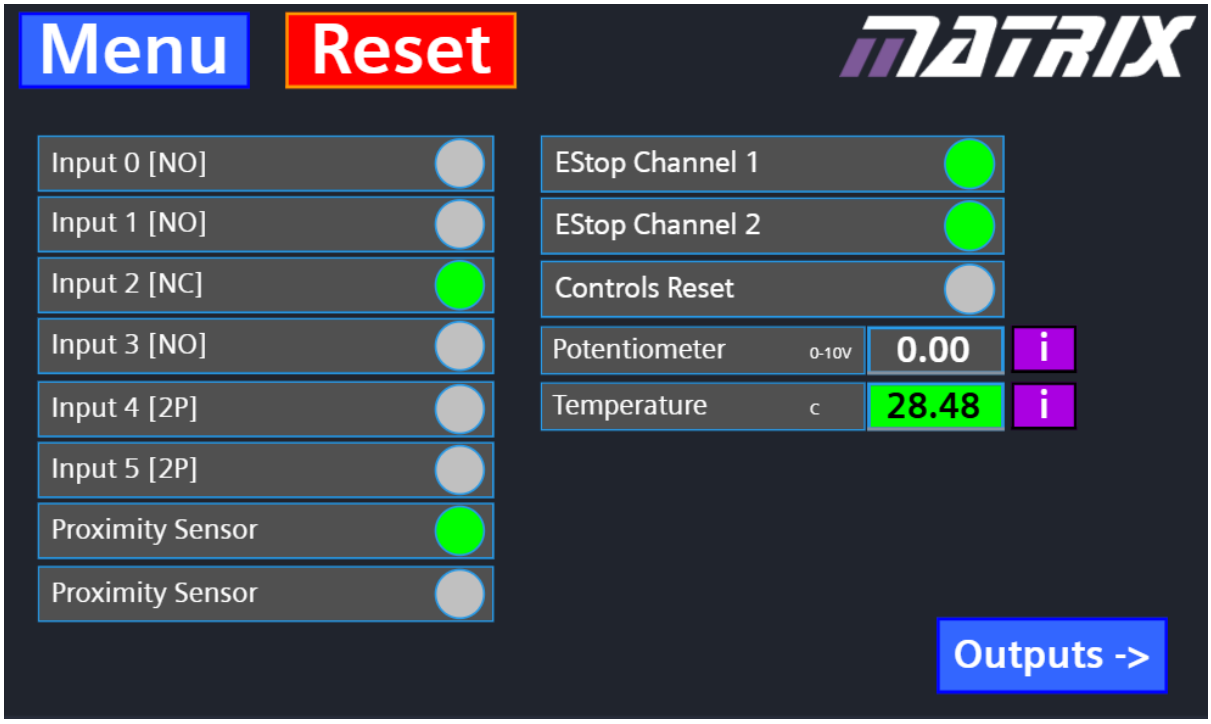
Always press Reset after resolving any fault to re-enable control logic.

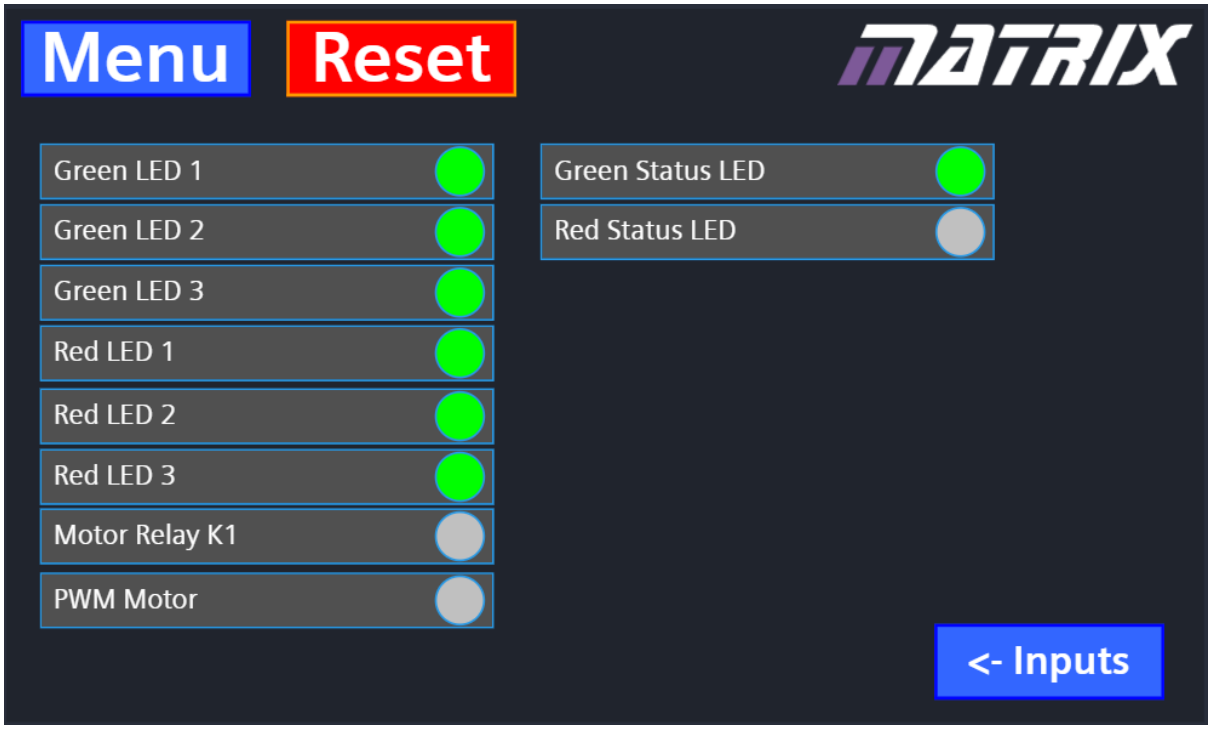
The reset button is mounted on the top left of the physical system and also shown on the top of a few of the HMI pages. You can find the reset button on the fault popup window,



IO Screen

The IO screens are a diagnostic page that shows the real-time status of the systems inputs and outputs. It is a vital tool for fault diagnosis, signal tracing, and verifying system behaviour during operation.





• Digital Inputs: Shows real-time status of physical inputs connected to the PLC, including emergency stops, push buttons, selector switches, proximity sensor, and the temperature signal input.

• Digital Outputs: Displays the status of output signals sent from the PLC to actuators and indicators, such as relays, LEDs and motors.

• Analogue Inputs and Scaling: Provides live values for:

- Potentiometer position (0-10 V scaled to 0-100%)
- PT100 Temperature Sensor (scaled °C value and raw voltage)

These screens allow learners to monitor how real-world signals are read by the PLC and how it responds through its outputs.

Interpreting the Colours

Each digital indicator lights green when its signal is ON and turns grey when OFF. However, green does not always mean “good”, it simply reflects the sensor’s electrical status. You must interpret this in context:

Input	Status = Green	Status = Grey	Interpretation
Reset Button	Being pressed	Not pressed	Grey is normal: button not in use
EStop Channels (NC)	Circuit complete	Open (E-Stop pressed or fault)	Grey = Fault or system halted
Proximity Sensor (NO)	Metal detected	No detection	Grey = Normal when nothing nearby
Potentiometer (AI)	Live voltage input	No input / disconnection	Grey may indicate a fault (broken wire etc)

While green typically indicates an input is active or "on," this does not always mean everything is OK. Context matters:

- Reset Button [NO]: If this input shows green, it means the button is being physically held down. This is not normal during standard operation and may indicate the button is stuck or being pressed unnecessarily.
- Emergency Stop [NC]: Normally closed inputs like the E-Stop should stay green during healthy operation. If they turn grey, it means the circuit has opened, signalling the system is in a fault or stop condition.

Always interpret input colours based on the device type and logic configuration, green does not always mean "good."

Using This Screen in Practice

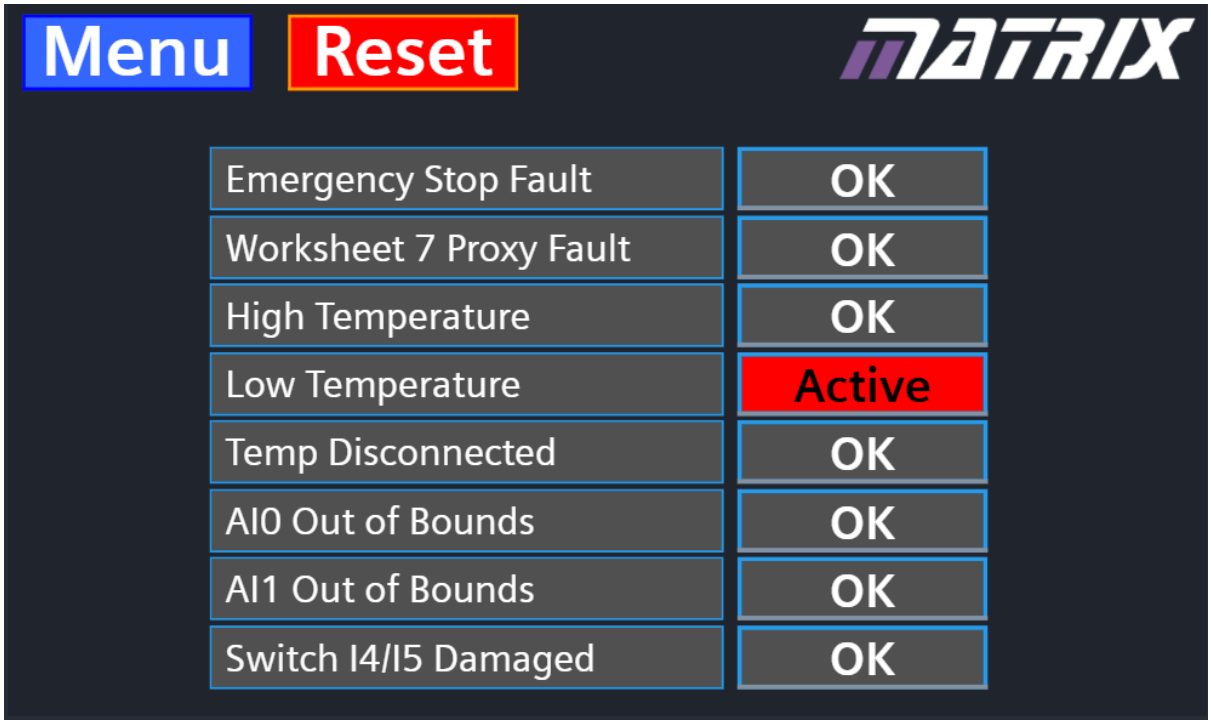
- During troubleshooting, check the state of each input here first. Compare the HMI status with actual sensor conditions.
- Use the “i” buttons next to each analogue signal to view or apply an offset (advanced users only).
- Remember that certain faults like intermittent proximity switch behaviour or temperature sensor offsets may only be visible here.

Summary

- Green = ON, Grey = OFF. Importantly, not good vs bad.
- Understand the logic type of each input (e.g. NC or NO) to interpret correctly.
- Use this screen as your first check when the system won’t start or behaves unpredictably.

Faults Screen

The Faults screen displays the live status of critical system conditions. It helps you quickly identify whether any active fault is preventing the system from running safely or correctly.



How it works

Each row represents a predefined fault condition monitored by the PLC. The status shown on the right indicates whether that fault is currently active or not.

- A status of OK means the condition is normal and not currently triggering a fault.
- If a fault occurs, the status will change to “ACTIVE”.

The Reset button in the top-right corner allows you to clear latched faults once the issue has been resolved.

Fault conditions monitored

- **Emergency Stop Fault:** Checks if the dual-channel E-Stop circuit is open or if the Emergency Stop is pressed.
- **Worksheet 7 Proxy Fault:** Detects issues with the proximity sensor used in Worksheet 7 (such as a missing or stuck target).
- **High Temperature:** Triggered if the measured temperature exceeds the configured upper safety limit.
- **Low Temperature:** Triggered if the measured temperature drops below the configured lower limit.
- **Temp Disconnected:** Indicates the temperature sensor is not detected (e.g., disconnected wiring or sensor fault).
- **AI0 Out of Bounds:** Detects if Analogue Input 0 (AI0) is outside the valid range (e.g., wiring error or sensor fault).
- **AI1 Out of Bound:** Detects if Analogue Input 1 (AI1) is outside the valid range.
- **Switch I4/I5 Damaged:** Checks for faults in the 3-position selector switch (inputs I4/I5), such as both signals being active at once or neither responding.

What you should do

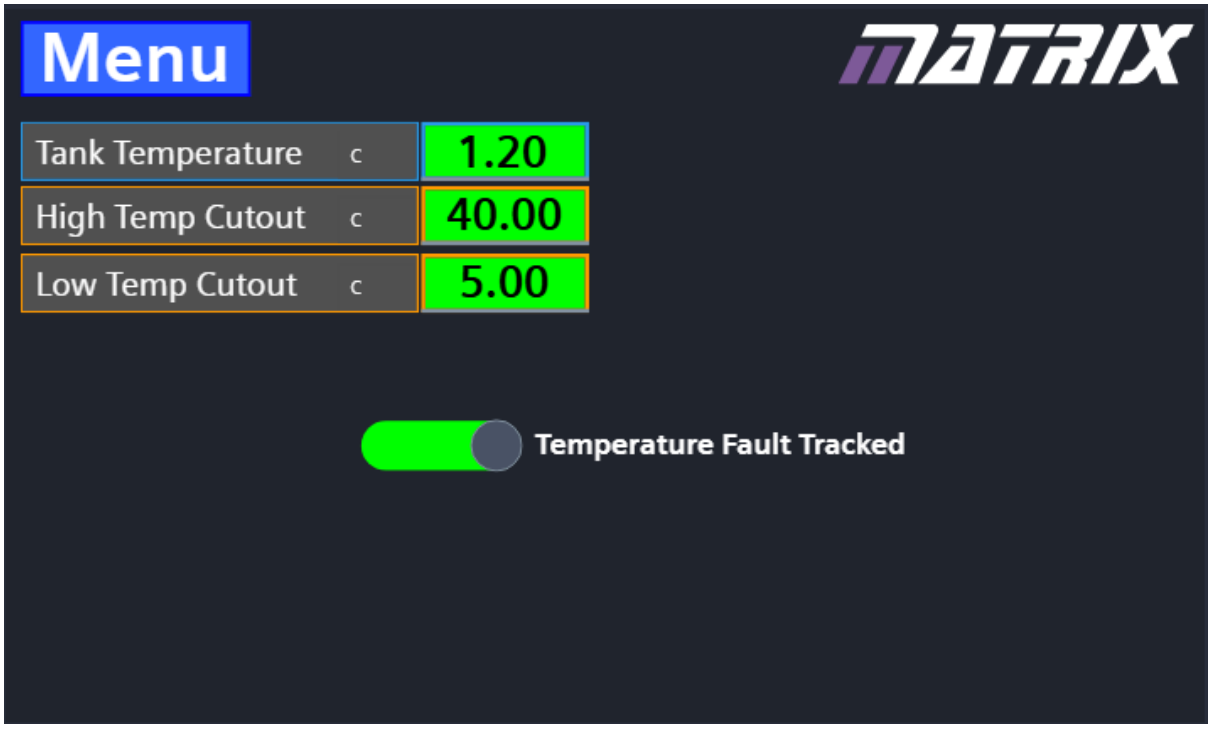
- Check this screen if the system fails to start or stops unexpectedly.
- Confirm all fault statuses are showing OK before attempting to run the system.
- If a fault is active, investigate the root cause (e.g. lid open, low water, high temperature).
- Once resolved, press Reset to clear the fault and attempt a system restart.

This screen is used during normal operation but is intentionally disabled during scenario-based training, where you are expected to diagnose faults using observation and the IO screen.

Setup Screen

Setup Screen Page 1

This screen allows you to adjust temperature limits and enable/disable temperature faults.

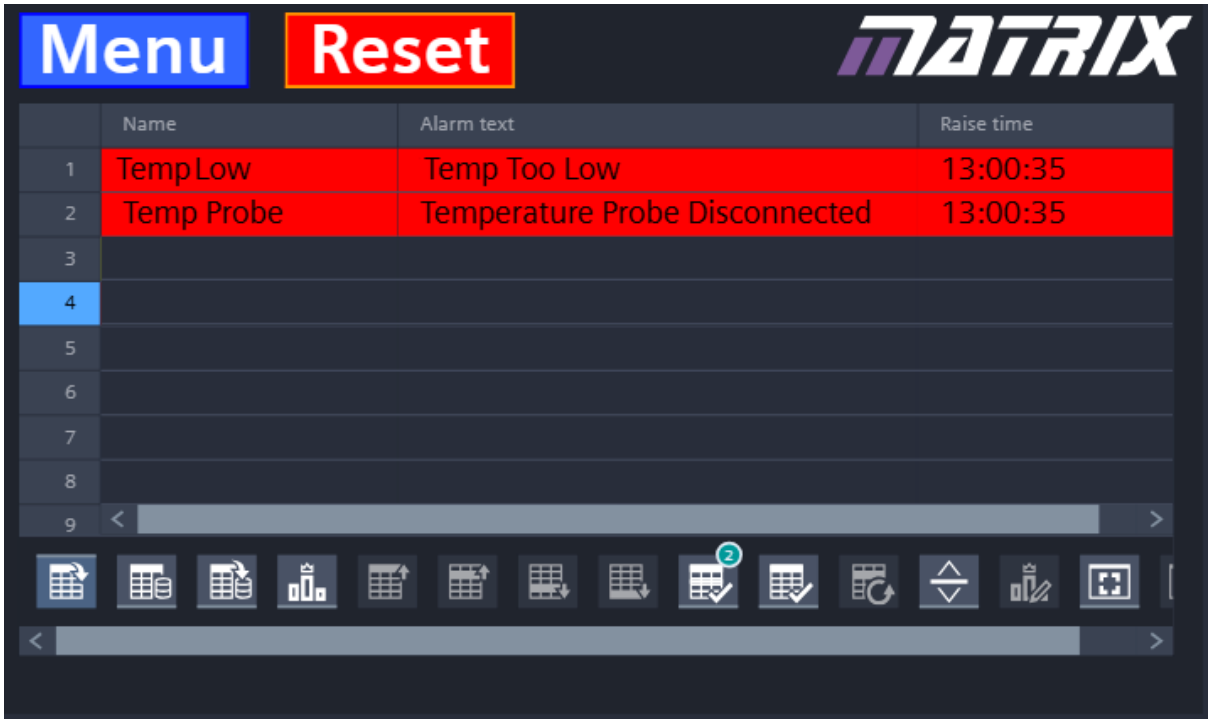


Temperature settings

- Temperature shows the live reading from the temperature sensor.
- High Temp Cutout defines the maximum allowable temperature. If exceeded, the system will shut down.
- Low Temp Cutout defines the minimum allowable temperature. If the ambient temperature drops below this value, the system will stop.

Alarms Screen

The Alarms screen displays a live list of all currently active alarms. These are triggered when the system detects conditions that may prevent safe or reliable operation.



Alarm table

Each row shows:

- the name of the alarm source
- a brief description of the problem
- the exact time the alarm was triggered

Alarms are colour-coded. Red indicates a critical condition that must be resolved before the system can restart.

Examples of alarm conditions include:

- emergency stop pressed or wiring fault detected
- temperature outside of safe limits

Resetting alarms

Use the Reset button at the top of the screen to clear all resolved alarms. The system will not reset automatically. You must first correct the fault (e.g. release the E-Stop) before pressing Reset.

Navigation

Use the Menu button in the top left to return to the main menu. If many alarms are present, scroll or navigate using the arrow and page controls at the bottom of the screen.

What you should do

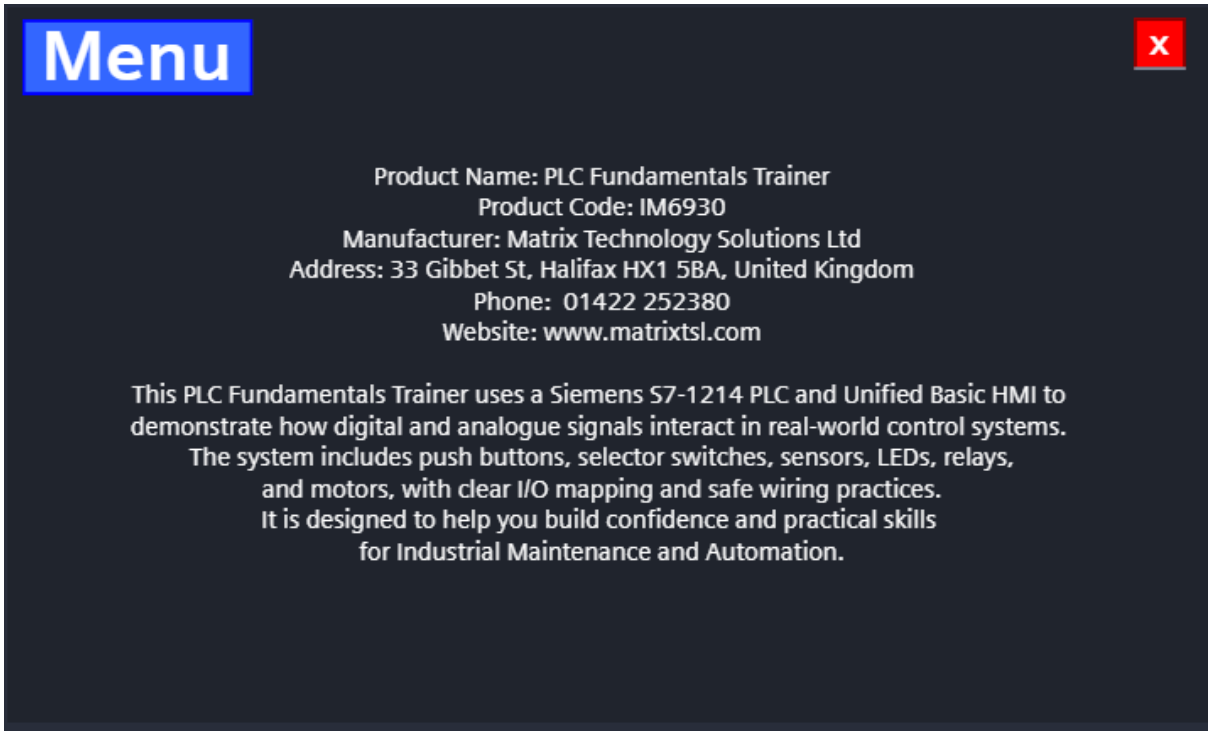
- check this screen any time the system stops running unexpectedly
- read the alarm text carefully to understand what has triggered the fault
- resolve the issue and press Reset to clear the fault state

The alarms screen is a key diagnostic tool and is available during normal operation.

Accessing Siemens Internal HMI Settings

To access the internal HMI settings, navigate to the About page.

Pressing the red “X” button on the top right of the About page will shut down the runtime and take you to the Siemens settings. There should be no need for you to ever do this and it is not advised to edit any settings here unless you are experienced.



MAINTENANCE & CALIBRATION

This system does not require much regular maintenance but nonetheless there should be some care taken to ensure reliable performance, accurate readings, and safe operation.

The tasks below should be performed according to the schedule shown. Maintenance should only be carried out by trained staff.

12.1 Maintenance schedule

Task	Interval	Method
Visual inspection	Before each class	Briefly check for loose wires, damaged connectors, and secure terminals.
Functional test	Weekly	Power on system, verify all indicators, buttons, and HMI operate correctly.
Cable & connector check	Monthly	Inspect all external cables, plugs, and connectors for wear or damage.
Clean exterior	Monthly	Wipe down enclosure and HMI touchscreen with a soft, dry cloth.
Firmware & program check	Termly/Before term	Confirm PLC and HMI firmware is up-to-date; verify default program loaded.
Calibration check (analogue inputs)	Annually	Use a known reference voltage or temperature probe to confirm analogue readings are accurate within expected range.
Safety devices	Before each term	Test emergency stop, reset, and circuit breaker for correct operation.

TROUBLESHOOTING

System Won’t Start

Faults Screen

- Check the Faults table on the Faults screen.
- There are only a few reasons why the system won’t start.
- The PLC is checking the faults table shown on the Faults Screen. If any of them are active, the system won’t run.
- The Status LED must be green for the system to run (except on worksheets related to the Status LED).

Check Power Supply

- Confirm the 24V DC adapter is plugged in securely to both the wall socket and the unit.
- Check the MCB (circuit breaker) on the front panel is switched ON.
- Ensure the power LED (if fitted) is illuminated on the unit or HMI.

Inspect Cables & Connections

- Visually check all external cables and connectors for damage or looseness.
- Gently press on terminal blocks to ensure all wiring is secure.

Emergency Stop & Reset

- Check the Emergency Stop button: Twist to release if pressed in.
- Press the blue Reset button on the panel.
- Confirm on the HMI that no emergency stop fault is active.

Fuse and MCB

- Inspect the fuse (if accessible) and replace if blown.
- Cycle the MCB off and on.

HMI & PLC Status

- Check the HMI screen: If blank, check power and backlight. If error/fault, note the message.

Troubleshooting

- Check PLC status LEDs: A steady green "RUN" LED means normal operation. Red or flashing LEDs may indicate a fault—note any error codes.

Check for Loose Components

- Open the enclosure (if permitted) and visually check for loose modules or connectors inside.

Default Program

- If you suspect software corruption, reload the default PLC and HMI program (see manual or contact support).

Other Checks

- Ensure no objects are blocking sensors or pressing buttons unintentionally.
- Allow the unit to acclimate if moved from a cold to warm environment (condensation can cause temporary issues).

Contact Support

If none of the above steps resolve the issue, contact Matrix TSL support. Have your product serial number, purchase date, and a description of the problem ready.

CRITICAL SPARES

This system uses standard, commercially available components that can be replaced as needed. Most parts are not considered critical, and replacements can typically be sourced through major suppliers. However, downtime should be accounted for when planning lessons.

Two components are considered critical due to their essential role in powering and protecting the system. These are recommended for on-site storage to minimise disruption:

Item	Part number / Order Code	Qty	Notes
Power Supply (24 V DC, 60 W)	Mean Well GEM60I24 P1J	1	IEC C8 inlet, main system PSU
Mini Blade Fuse (3 A, violet)	RS PRO 563-712	1	32 V DC mini blade fuse for WAGO fuse terminal, essential circuit protection

Important note:

The PLC and HMI are pre-programmed with custom Matrix software. If either unit is damaged or requires replacement, the new device will not function correctly without reloading the project files. This process requires specific technical knowledge and is not intended to be carried out by the end user. If you need to replace the PLC or HMI, please contact Matrix Technology Solutions for technical support or reprogramming services.

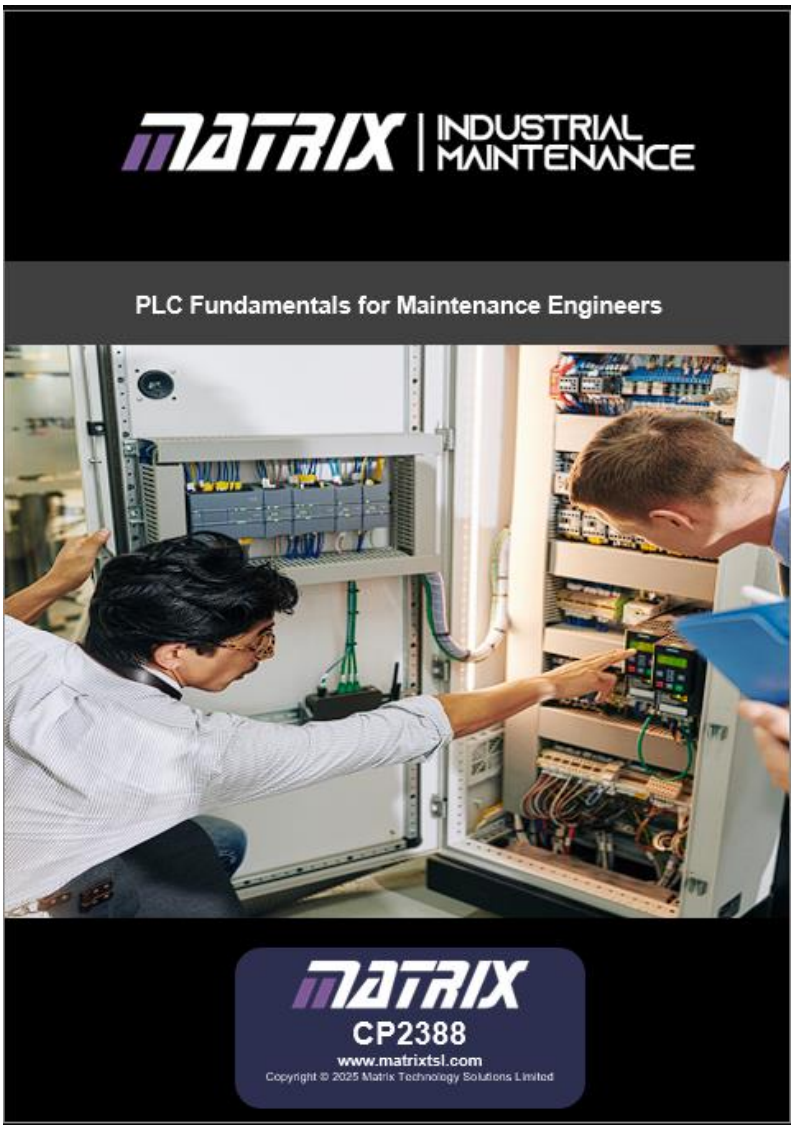
TEACHING & ASSESSMENT AIDS

For training environments using this equipment, structured worksheets are available separately:

- CP2388 – PLC Fundamentals for Maintenance Engineers

Refer to this documents for further information on structured procedures, fault analysis, and control system behaviour.

CP2388 – PLC Fundamentals for Maintenance Engineers



WARRANTY & SUPPORT

12 months parts & labour from invoice date.

Warranty void if operated outside specs, modified, or unclean water is used.

For support:

Email: support@matrixtsl.com

Phone: +44 (0)1422 252 380

Quote serial number: IM0004

Appendix A – Electrical Drawings

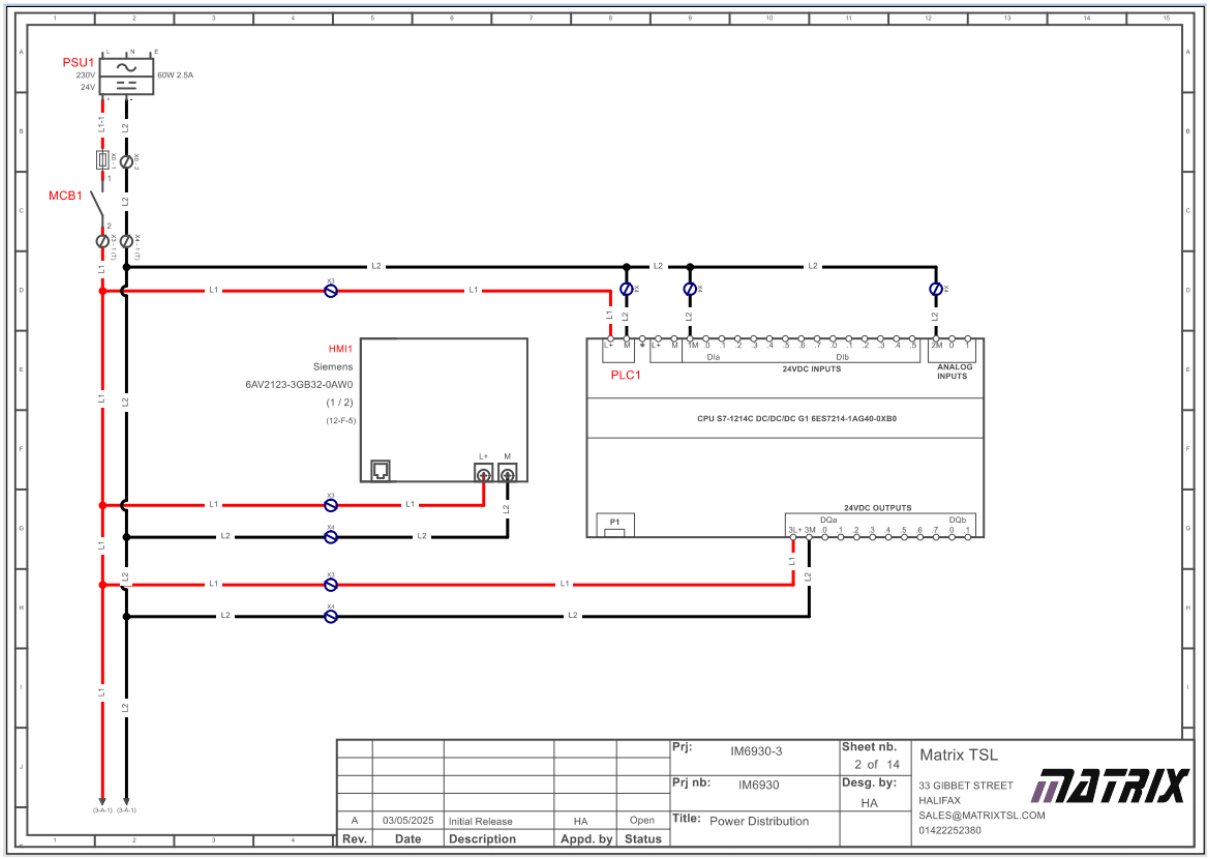
APPENDIX A – ELECTRICAL DRAWINGS

IM6930-3 (Table of contents)

Rev.	Date	Description	Appd. by	Status
A	03/05/2025	Initial Release	HA	Open

Prj: IM6930-3 | Prj nb: IM6930 | Title: Table of Contents | Sheet nb. 1 of 14 | Desg. by: HA

Matrix TSL
33 GIBBET STREET
HALIFAX
SALES@MATRIXTSL.COM
01422252380

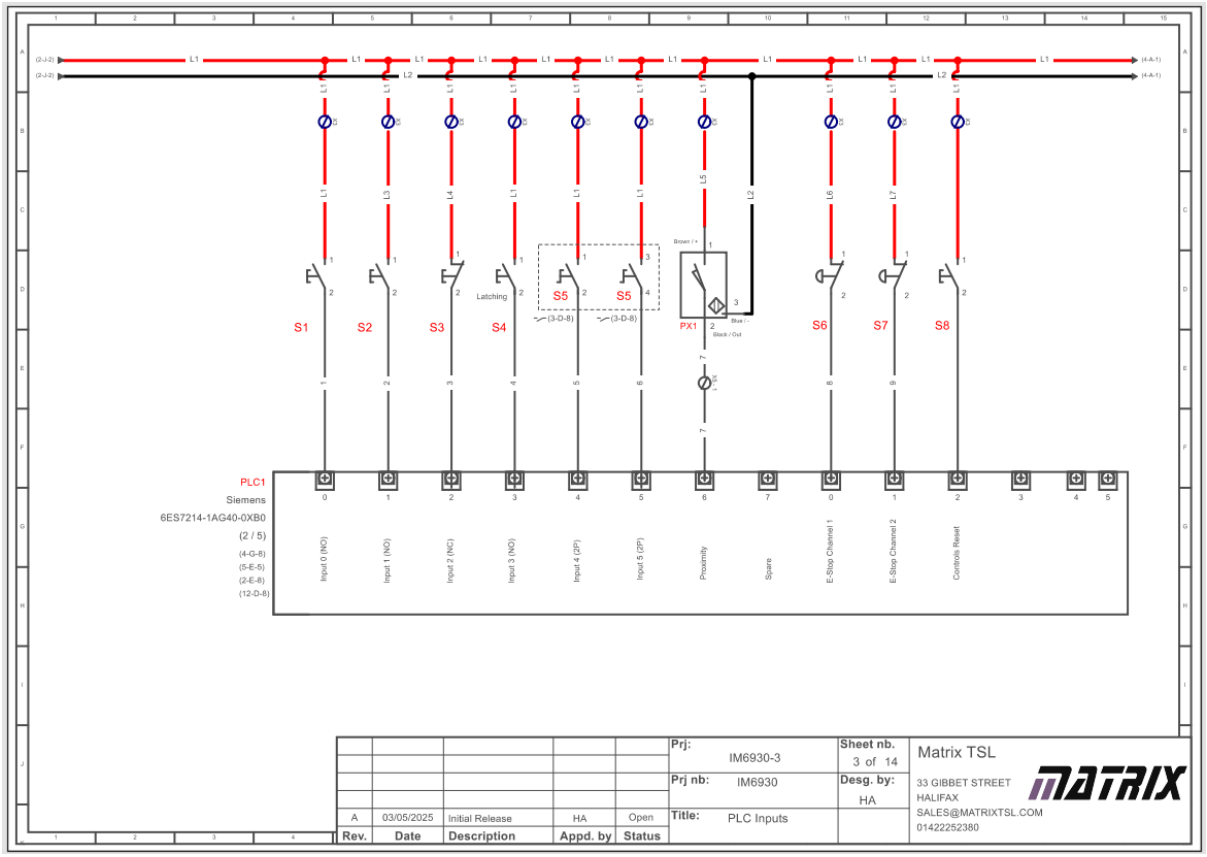


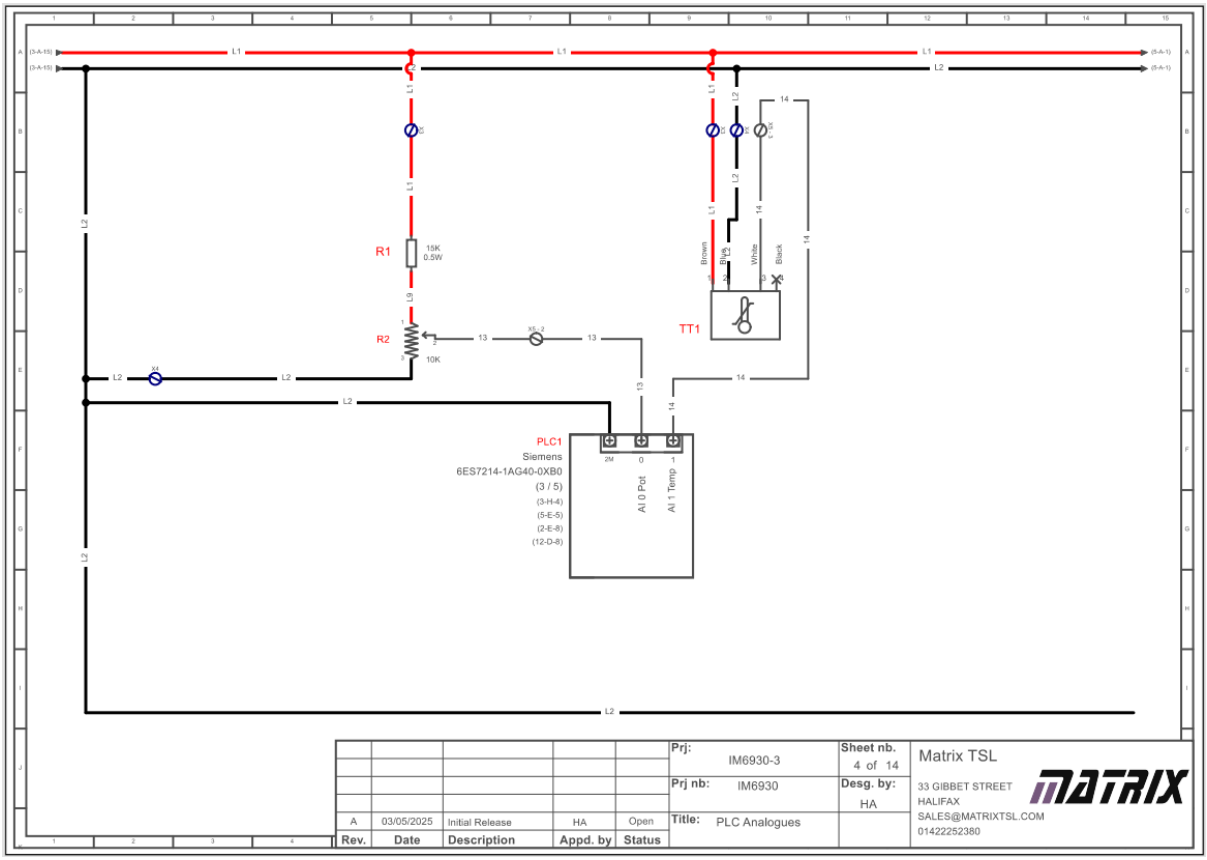
Rev.	Date	Description	Appd. by	Status
A	03/05/2025	Initial Release	HA	Open

Prj: IM6930-3 | Prj nb: IM6930 | Title: Power Distribution | Sheet nb. 2 of 14 | Desg. by: HA

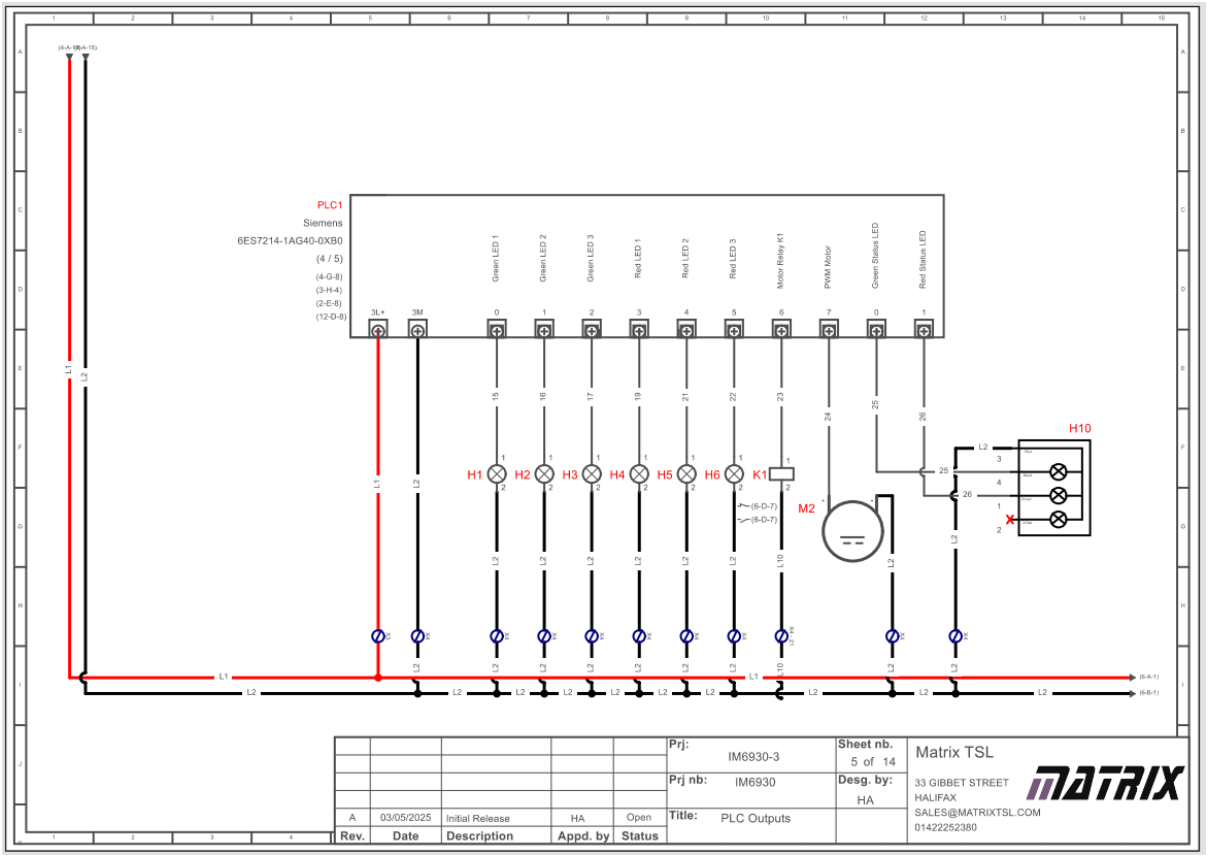
Matrix TSL
33 GIBBET STREET
HALIFAX
SALES@MATRIXTSL.COM
01422252380

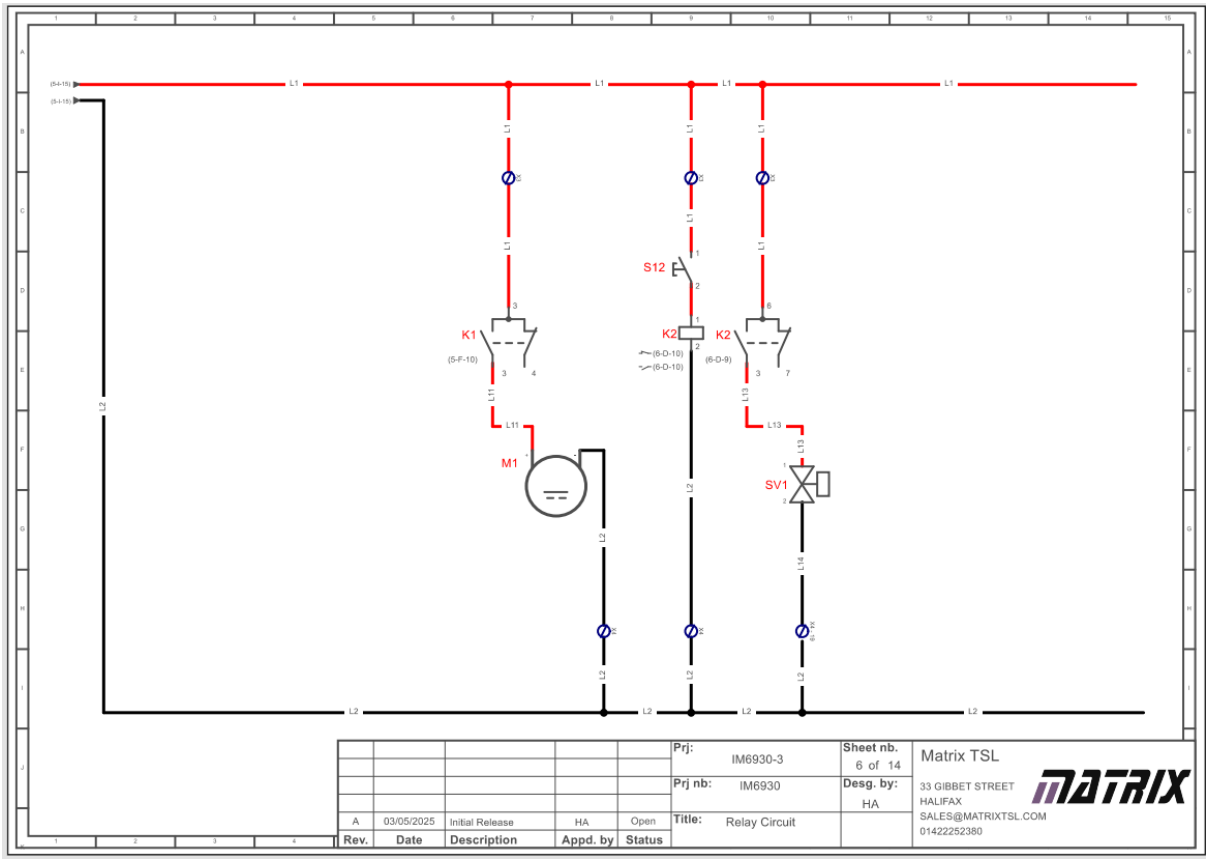
Appendix A – Electrical Drawings



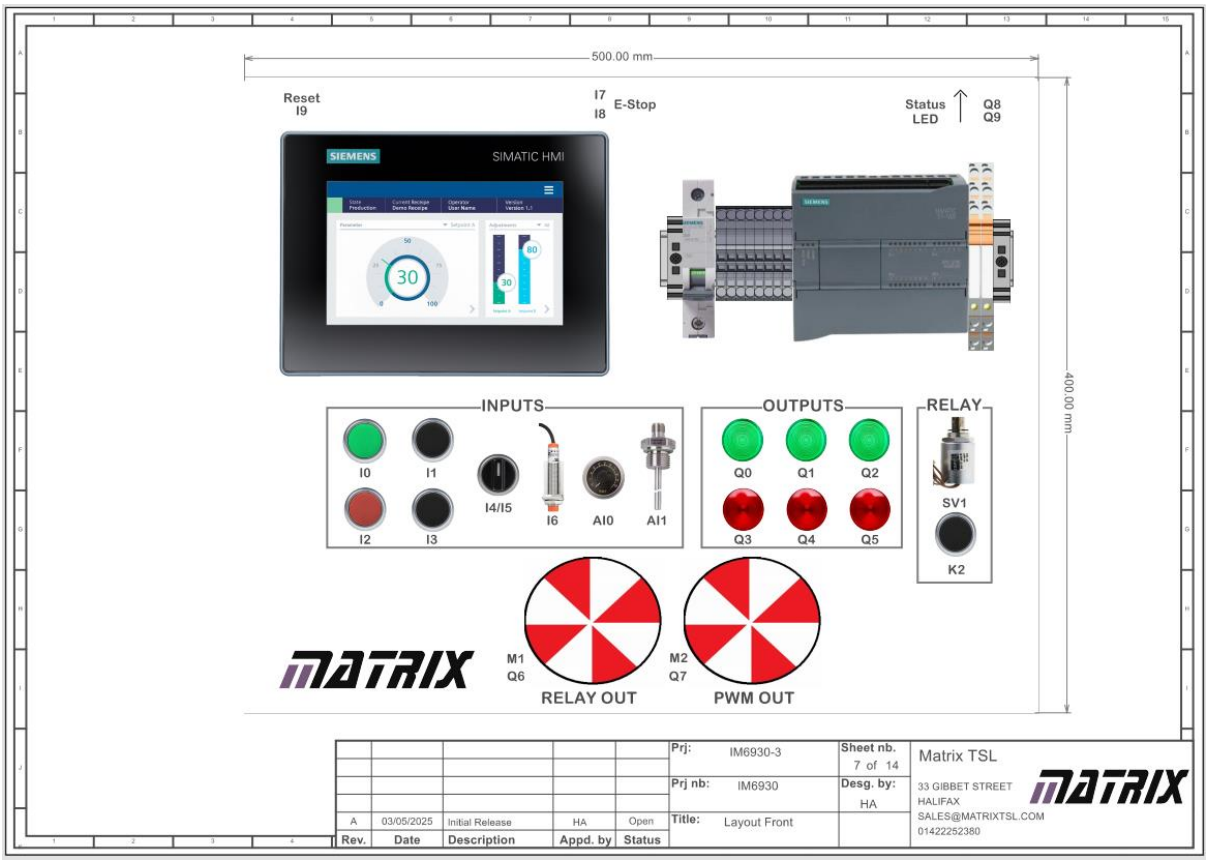


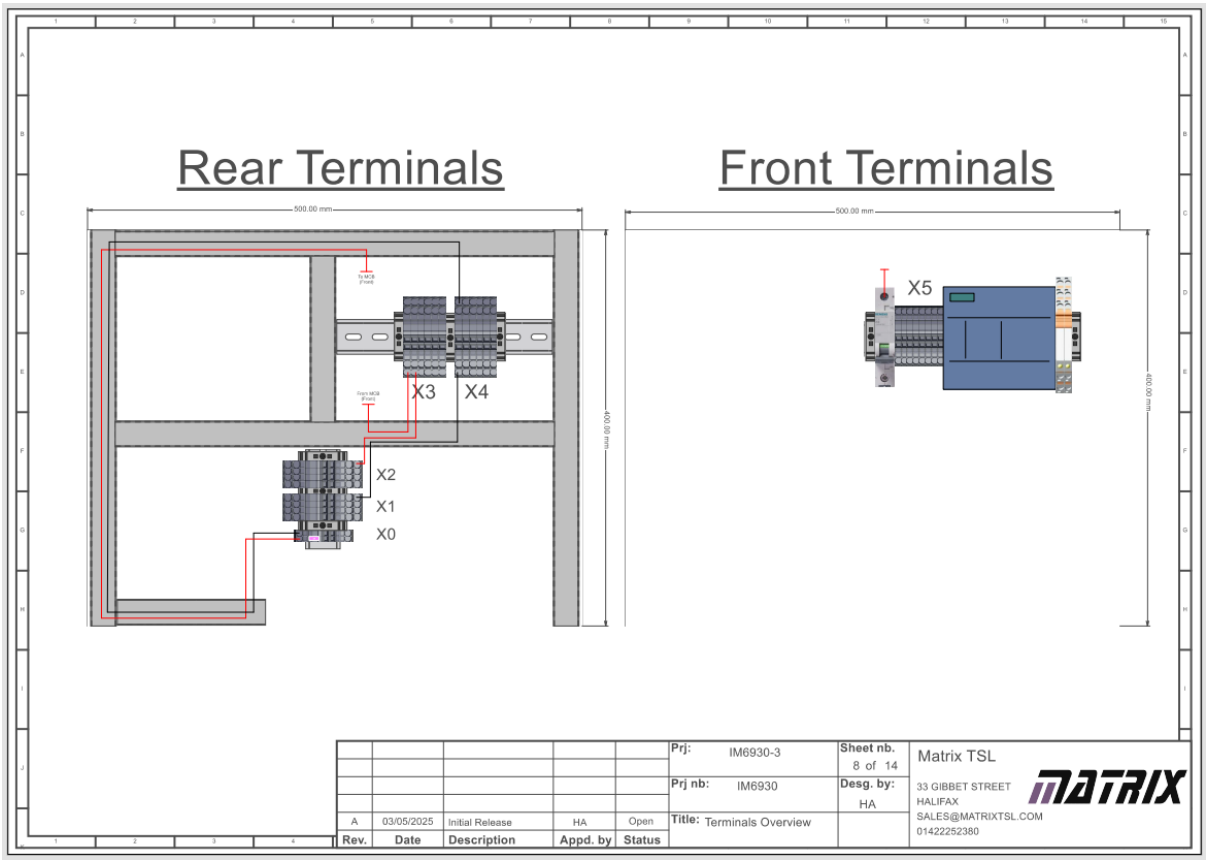
Appendix A – Electrical Drawings



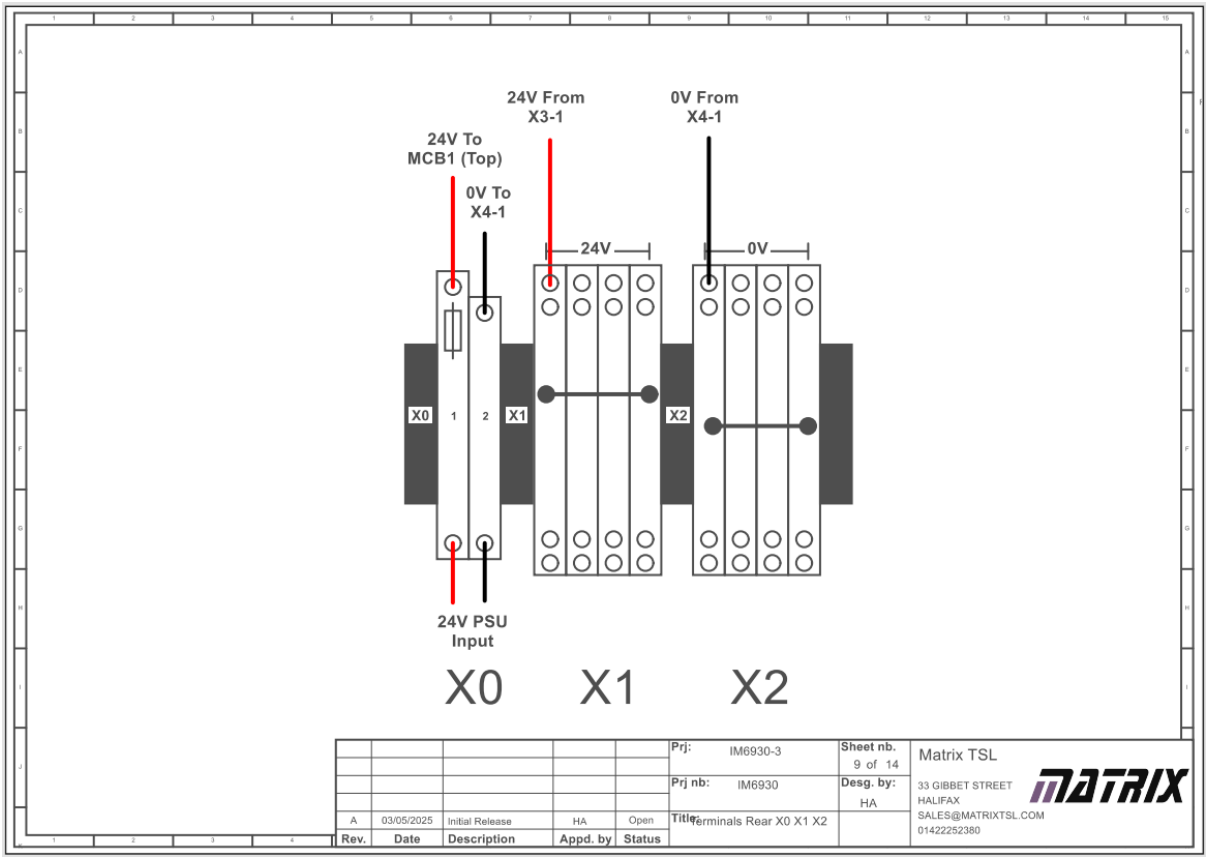


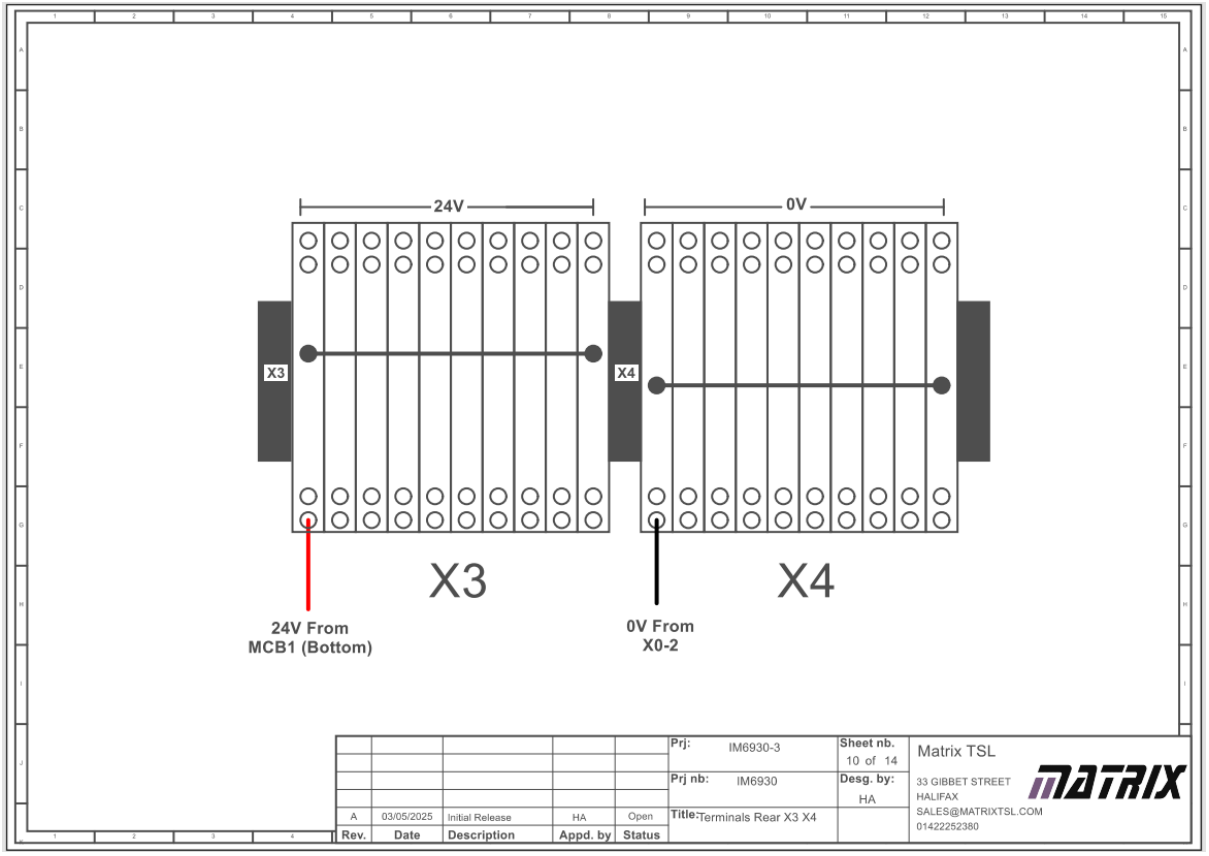
Appendix A – Electrical Drawings



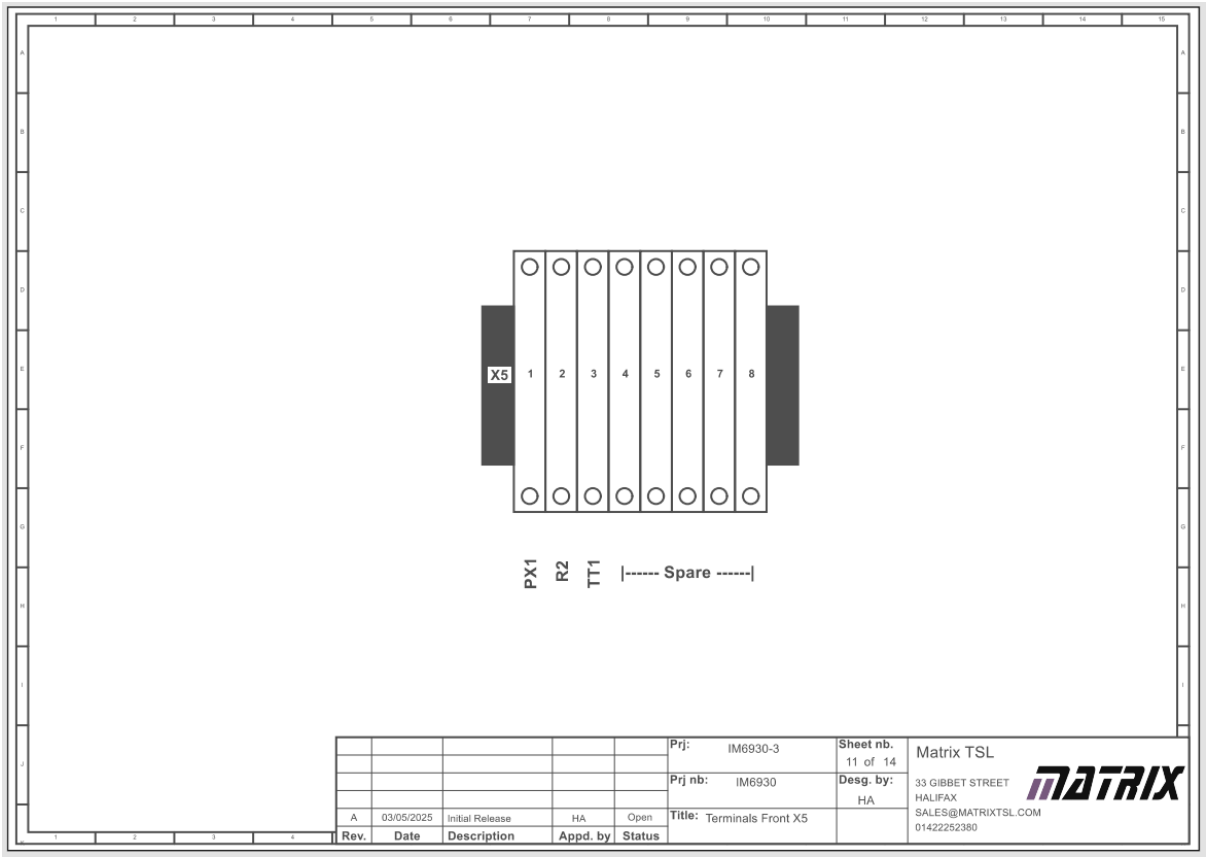


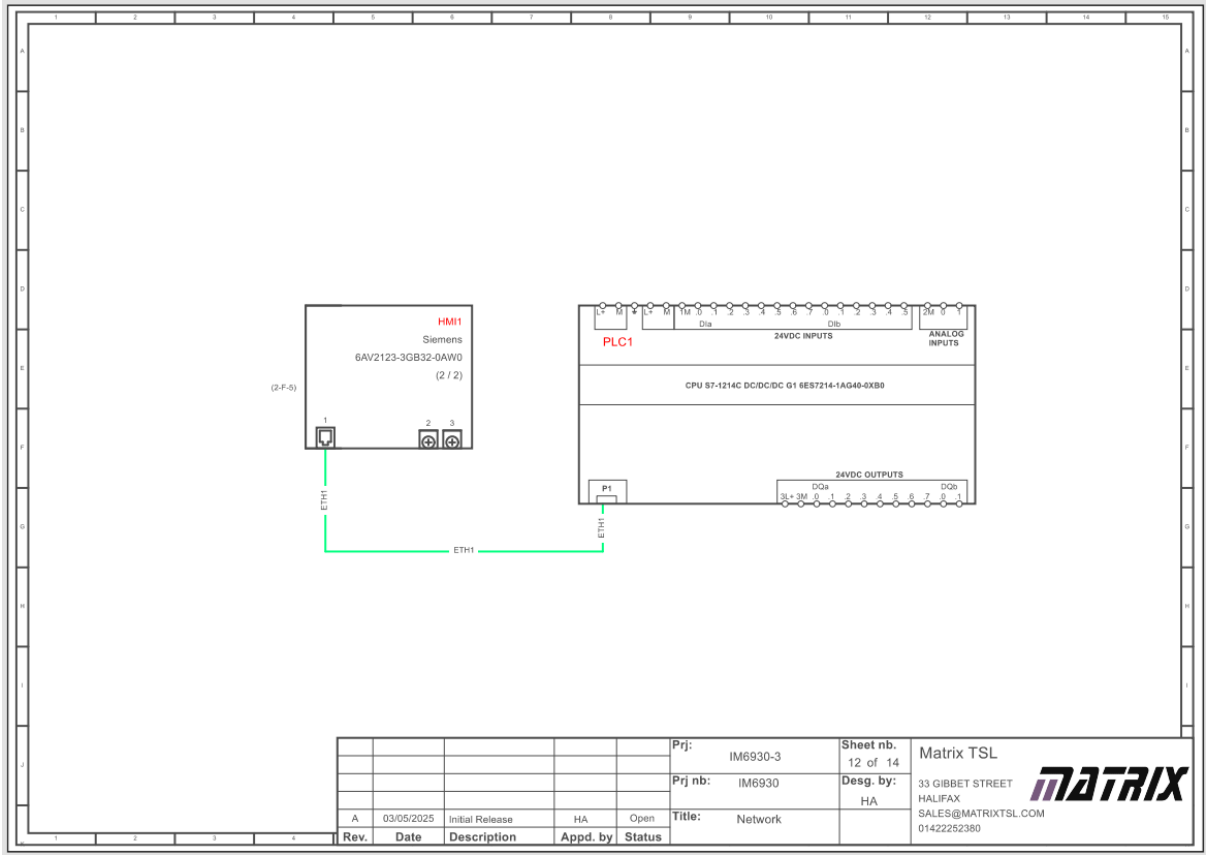
Appendix A – Electrical Drawings





Appendix A – Electrical Drawings





Appendix B – Bill of Materials

APPENDIX B – BILL OF MATERIALS

Ref	Class name	Description	Manufacturer	Part number	Qty
F1	Fuse holder	WAGO TOPJOB S Series Grey, 2.5mm², 1-Level, Push In Termination, Fused, CSA	Wago	2002-1681	1
F1	Fuse	3A Violet Mini Blade Car Fuse, 32V dc	RS Pro	563-712	1
H1	Indicator	Green LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7918	1
H2	Indicator	Green LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7918	1
H3	Indicator	Green LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7918	1
H4	Indicator	Red LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7909	1
H5	Indicator	Red LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7909	1
H6	Indicator	Red LED Pilot Light, 22mm Cutout, IP65, Round, 24V ac/dc	RS Pro	763-7909	1
H10	Indicator	Banner K50L Series Green, Red, Yellow Beacon, 18 → 30 V dc, Base Mount, LED Bulb, IP67, IP69	Banner	K50LGRYPQ	1
H10	Wire management accessory	Straight Female 4 way M12 to Actuator/Sensor Cable, 1m	RS Pro	283-4880	1
HMI1	HMI	SIMATIC HMI MTP700, Unified Basic Panel, touch operation, 7" widescreen TFT display	Siemens	6AV2123-3GB32-0AW0	1
K1	Relay	Interface Relay, DIN Rail Mount, 24V ac/dc Coil, 1-Pole	Wago	857-314	1
M1	Motor	DC Gear Motor, 30:1, 12–24 V, 4mm Shaft	MFA	918D30112/1	1
M2	Motor	DC Gear Motor, 30:1, 12–24 V, 4mm Shaft	MFA	918D30112/1	1
MCB1	Circuit Breaker	Siemens SENTRON 5SY MCB, 1P, 3A Curve B	Siemens	5SY4103-7	1

Appendix B – Bill of Materials

PLC1	PLC	CPU 1214C - 24 VDC PSU, 14 DI (24 VDC), 10 DQ (24 VDC), 2 AI (0-10V), 150kB	Siemens	6ES7214-1AG40-0XB0	1
PSU1	Power supply	AC-DC 24V PSU	MEAN WELL	GEM60I24-P1J	1
PX1	Proxy Switch	Inductive Threaded Barrel Proximity Sensor, M12, 16 mm Detection, PNP NO, 10 → 30 V dc	Omron	E2E-X16MB1T12 2M	1
R1	Fuse holder	WAGO TOPJOB S Series Grey, 2.5mm², 1-Level, Push In Termination, Fused, CSA	Wago	2002-1681	1
R1	Accessory	15K Resistor 0.5W	TE Connectivity	CFR50J15K	1
R2	Potentiometer	10kΩ Rotary Potentiometer, 1SFA611410R1106 MT-110B 10 K OHM	ABB	1SFA611410R1106 MT-110B 10 K OHM	1
S1	Button	Pushbutton, 22 mm, round, metal, high gloss, green, button, 1 NO	Siemens	3SU1150-0AB40-1BA0	1
S2	Button	Pushbutton, 22 mm, round, metal, high gloss, green, button, 1 NO	Siemens	3SU1150-0AB40-1BA0	1
S3	Button	Pushbutton, 22 mm, round, metal, high gloss, red, button, 1 NC	Siemens	3SU1150-0AB20-1CA0	1
S4	Button	Pushbutton, 22 mm, round, metal, high gloss, red, button, 1 NC	Siemens	3SU1150-0AB20-1CA0	1
S5	Selector switch	Toggle switch, illuminable, 22 mm, round, metal, high gloss, white, 1 NO, 1 NO	Siemens	3SU1150-2BL60-1NA0	1
S6	EStop	Contact module with 1 contact element, 1 NC	Siemens	3SU1400-1AA10-1CA0	1
S7	EStop	Contact module with 1 contact element, 1 NC	Siemens	3SU1400-1AA10-1CA0	1
S8	Button	Blue SIRIUS ACT 3SU11 Series Push Button Complete Unit, Panel Mount, 22mm Cutout, SPST	Siemens	3SU1150-0AB50-1BA0	1

Appendix B – Bill of Materials

S9	EStop	Backing plate round, for emergency stop mushroom pushbutton, yellow: Emergency Stop	Siemens	3SU1900-0BC31-0DA0	1
S10	EStop	Emergency stop mushroom pushbutton, 22 mm, round, metal, high gloss, red, rotate-to-unlatch mechanism	Siemens	3SU1050-1HB20-0AA0	1
S11	Button	Button/LED Holder for 3 modules, plastic	Siemens	3SU1500-0AA10-0AA0	1
TH1	Thermocouple & RTD	Electronic PT100 RTD Sensor, 6mm Dia, 12mm Long, 4 Wire, G1/2, +150°C Max	IFM	TM4101	1
TT1	Temp. Transmitter	Evaluation unit for PT100/PT1000 temperature sensors	IFM	TP9237	1
TT1	Wire management accessory	Right Angle Female 4 way M12 to Unterminated Sensor Actuator Cable, 2m	RS Pro	212-1703	1
X1	Power Distribution Block	4-conductor through terminal block; 2.5 mm²; for DIN-rail 35 x 15 and 35 x 7.5; Push-in CAGE CLAMP®; 2,50 mm²; gray	Wago	2002-1401	7
X1	DIN rail accessory	WAGO, 22 (TOPJOB S) Jumper for use with for use with Terminal Blocks	Wago	2002-406	4
X1	Terminal block accessory	249 Group Marker Carrier	Wago	249-119	4
X1	Terminal block accessory	Screwless end stop; 6 mm wide; for DIN-rail 35 x 15 and 35 x 7.5; grey	Wago	249-116	8
X2	Power Distribution Block	4-conductor through terminal block; 2.5 mm²; for DIN-rail 35 x 15 and 35 x 7.5; Push-in CAGE CLAMP®; 2,50 mm²; gray	Wago	2002-1401	7
X3-X4	Power Distribution Block	4-conductor through terminal block; 2.5 mm²; for DIN-rail 35 x 15 and 35 x 7.5; Push-in CAGE CLAMP®; 2,50 mm²; gray	Wago	2002-1401	6
X5	Power Distribution Block	2-conductor through terminal block; 2.5 mm²; for DIN-rail 35 x 15 and 35 x 7.5; Push-in CAGE CLAMP®; 2,50 mm²; gray	Wago	2002-1201	5

Appendix C – Risk Assessment Summary

APPENDIX C – RISK ASSESSMENT SUMMARY

RISK	LIKELI-HOOD	IMPACT	RISK RATING	RESPONSE (ACTION)
Incorrect Power Supply Used or Incorrect Voltage applied. This could damage the components and be a hazard should they use mains voltage.	2	4	8	We have used a DC barrel jack for our power input, which mitigates against someone trying to input 240V IEC connector. We will label the power input as 24V only. We will also attach a 4A fuse internally in the product to additionally mitigate against incorrect power input.
Motor is stalled or shaft is prevented from rotating, causing excessive current draw on the PLC digital output and potential damage to the PLC output circuit.	2	3	6	The PLC outputs are rated for moderate loads and protected by an internal fuse. Users are instructed not to forcibly stall the motor or block the shaft. If a stall is detected (e.g. output not behaving as expected), users are to power off immediately and inspect for obstructions. Clear training and warnings are provided in documentation. For critical use, the output circuit can be externally fused for additional protection. Motor is specified for short-duty demonstration only.
Incorrect connection of external devices to I/O terminals resulting in damage to PLC or wiring.	2	3	6	Only pre-wired, labelled terminals should be used. Adding or modifying wiring is restricted to qualified personnel. Clear instructions provided; warranty void if wiring is modified by unqualified users.
Failure to isolate power before servicing, risking minor shock or damage.	2	3	6	Clear warning labels on enclosure and in manual. Power must be isolated using the MCB before any maintenance or inspection. Training emphasizes correct isolation procedure.
Emergency stop does not physically cut power and the system relies on non-safety-rated PLC logic for stop function (pseudo E-Stop). In a real emergency, someone may press it expecting full shutdown, but it may fail.	2	2	4	Although the E-Stop is software-based, the system operates at 24V with built-in short circuit and overload protection, plus a circuit breaker. The E-Stop will be clearly labelled as non-safety-rated. Documentation and training will reflect this limitation. Dual-channel monitoring of the E-stop circuit will be implemented in the PLC logic to detect wiring faults such as open circuit conditions on either channel. Each channel will be read independently, and the system will trigger a fault if either channel opens. This approach simulates dual-channel safety logic for non-safety applications and educational purposes only, and does not provide certified safety integrity.
Faulty or damaged external cable creates trip hazard in classroom/lab environment.	2	2	4	All cables supplied are of suitable length and flexibility, and should be routed safely away from walkways. Instructors should perform visual checks before each session. Damaged cables must be replaced immediately.
Small objects (e.g. loose wires, tools) may contact rotating motor, leading to	2	2	4	The protective screen fully encloses the motor area. Users are instructed to keep the area clear of tools and debris. Pre-use inspection is recommended before each session. If a foreign object enters the

Appendix C – Risk Assessment Summary

mi or equipment damage or jamming.				motor area, power must be isolated before removal.
Incorrect wiring during setup causes short circuit or component failure	3	1	3	The system runs on a 24V supply with built-in protection, so risk is limited. However, clear wiring diagrams and setup guides will be provided. All staff will be trained to safely wire the system and test it before operation.
Rotating motor shaft presents a minor entanglement or pinch hazard if touched during operation.	1	3	3	Motors are mounted behind a fixed transparent screen, preventing direct contact. The screen is secured and cannot be removed during normal operation. Users are instructed not to operate the system if the screen is damaged or missing. Clear safety labels are applied.
Exposed terminals or connectors pose shock hazard	2	1	2	All terminals operate at 24V DC. While electrical contact may cause small, harmless sparks, there is no shock hazard. Clear labelling and optional covers will be included to guide safe interaction.
Overheating of motors or relays due to blocked ventilation or excessive use, possibly causing component failure.	1	2	2	Motors and relays are specified for continuous operation at 24V. Trainer should be used in well-ventilated areas. Users are instructed to keep ventilation holes clear. Periodic checks recommended after extended operation.
Finger entrapment or injury due to insertion into ventilation holes on enclosure.	1	2	2	All ventilation holes are designed and tested to comply with relevant standards for finger safety (e.g., EN 60204-1), ensuring no finger can be inserted. Users are instructed not to insert objects into vent holes. Safety statement included in user manual.

	SEVERITY				
	1	2	3	4	5
1	LOW 1	LOW 2	LOW 3	MEDIUM 4	MEDIUM 5
2	LOW 2	MEDIUM 4	MEDIUM 6	HIGH 8	HIGH 10
3	LOW 3	MEDIUM 6	HIGH 9	HIGH 12	EXTREME 15
4	MEDIUM 4	HIGH 8	HIGH 12	HIGH 16	EXTREME 20
5	MEDIUM 5	HIGH 10	EXTREME 15	EXTREME 20	EXTREME 25

Severity Ratings (Aligned to EN ISO 12100 / 13849 Concepts)

Appendix C – Risk Assessment Summary

Severity	Description		Example from EN ISO/IEC Frameworks	
1 – Negligible	No injury or only superficial injury, no equipment damage		Minor spark, no hazard; operator startled but unharmed	
2 – Minor	Slight injury requiring first aid; minor equipment damage		Small burn, mild shock, or overshoot of flow without consequence	
3 – Moderate	Injury requiring medical treatment; moderate equipment downtime		Overheated valve or minor electrical fire (contained)	
4 – Serious	Serious injury (e.g., fracture), possible hospital stay; equipment disabled		Unexpected motion or system failure causing entrapment risk	
5 – Critical	Fatal or life-altering injury; catastrophic system damage		Contact with mains voltage, high-pressure rupture, etc.	

This risk assessment uses a Likelihood × Severity matrix to evaluate hazards associated with the product. Likelihood (1–5) reflects the probability of occurrence, while Severity (1–5) reflects the potential impact. Their product gives a Risk Rating (1–25). Risk levels are categorised as Low (1–3), Medium (4–6), High (8–12), or Extreme (15–25), helping to determine the appropriate level of response. Control measures detailed in the Response column include design features, documentation, labelling, and training, ensuring proportionate risk management while acknowledging the non-safety-rated nature of the PLC system.

Appendix D – CE Declaration

APPENDIX D – CE DECLARATION

EU Declaration of Conformity

Manufacturer: **Matrix Technology Solutions Ltd**
The Factory, 33 Gibbet Street, Halifax, West Yorkshire, HX1 5BA, United Kingdom

Product Description: **Industrial Maintenance PLC Fundamentals Trainer**
Model: **IM6930**
Comprising: Comprising: Siemens S7-1200 PLC, Siemens Unified Basic HMI, range of industrial push buttons (NO/NC), selector switch, potentiometer for analogue input, inductive proximity sensor, IFM temperature sensor with transmitter, dual-channel emergency stop, blue reset button, DIN-rail relays, indicator LEDs, and two DC motors for output demonstration. The system is integrated into a modular training rig designed specifically for educational environments.

Serial Numbers / Batch Numbers: **0-100**

We hereby declare under our sole responsibility that the above-mentioned product conforms to the following applicable Directives:

- Low Voltage Directive (2014/35/EU)
- Electromagnetic Compatibility (EMC) Directive (2014/30/EU)
- RoHS Directive (2011/65/EU as amended by 2015/863)

Applied Harmonised Standards:

- EN 61010-1:2010 – Safety requirements for electrical equipment for measurement, control, and laboratory use
- EN 61000-6-2:2019 – EMC Immunity for industrial environments
- EN 61000-6-4:2019 – EMC Emission for industrial environments

Technical Documentation Includes:

- Product description and intended educational use
- Circuit diagrams and wiring schematics
- Bill of Materials (BOM)
- Electrical and functional test reports
- Risk identification summary (non-machinery scope)
- Manufacturer's component declarations and CE certificates
- User manual and safety instructions

This declaration is made in accordance with the above Directives and is valid only when the product is installed, maintained, and used according to the accompanying documentation.

Technical File Contact: Liam Walton liam.walton@matrixtsl.com

Authorised Signatory:
Name: Hamed Adefuwa
Position: Electrical Engineering Product Manager
Place of Issue: Halifax, UK
Date of Issue: 03/05/2025
Signature: H.Adefuwa

VERSION CONTROL

15 07 25	First Revision Created

