

# 2320628

*by* Sion Phillips

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**Submission date:** 19-May-2025 03:23PM (UTC+0100)

**Submission ID:** 259803834

**File name:** 23236\_Sion\_Phillips\_2320628\_181809\_1718455625.pdf (1.45M)

**Word count:** 6138

**Character count:** 41086

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***Course:*** HNC Electrical / Electronic Engineering

***Module Code:*** SGEE 4006

***Assignment Title:*** Final Report and Log Book

***Date Submitted:*** 16/05/2025

***Word Count:*** 3895

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*Good list of figures*

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*Good use of tables*

## Introduction and Background Research

This project presents the development of a smart water temperature monitoring system for use within healthcare environments under the NHS Health Board. The system is designed to track the temperature of water leaving a Combined Heat and Power (CHP) system and arriving at ward-level distribution points within hospital buildings. This is a critical aspect of ensuring compliance with national water safety guidance particularly the Welsh Health Technical Memorandum (WHTM) 04-01 and in mitigating risks associated with Legionnaires' disease.



## Problem Statement and Context

Legionella bacteria can thrive in water systems where temperatures are inadequately maintained, posing a serious health risk in healthcare settings. Legionnaires' disease is a severe form of pneumonia primarily contracted through inhalation of aerosolized water droplets containing *Legionella pneumophila* (Health and Safety Executive, 2021). Patients in hospitals are particularly vulnerable, making water hygiene a fundamental concern. *Good point and ref source*

According to WHTM 04-01, hot water must be stored at a minimum of 60°C and distributed at a minimum of 55°C at the outlet to inhibit bacterial growth (NHS Wales, 2016). The challenge addressed by this project is that water loses heat as it travels through pipework from the CHP plant to terminal outlets in wards, which can result in temperatures falling below the safe range, particularly in older or more complex facilities.

Currently, many healthcare estates still rely on periodic manual checks or basic monitoring solutions that may not capture real-time changes or early warning signs of unsafe conditions (Public Health England, 2019). This project proposes a modernised solution: an automated, networked temperature monitoring system using industrial-grade sensors, real-time data access, and web-based control. *Good explanation*

## System Overview

The system utilises a Siemens programmable logic controller (PLC) to gather temperature data from a thermocouple Resistance Temperature Detector (RTD). RTD sensors are known for their high accuracy and linearity across a wide temperature range, making them ideal for industrial and healthcare use (Omega, 2023). The PLC serves as the control unit, continuously sampling sensor inputs and handling logic for alarm thresholds and data formatting.

One of the key features of this system is its remote accessibility via a web browser. This is achieved through the use of Asynchronous JavaScript And XML (AJAX) and JavaScript Object

Notation (JSON) technologies. AJAX is a client-side web development technique that allows data to be exchanged with a server and parts of a webpage to be updated asynchronously, without requiring a full page reload (MDN Web Docs, 2024). It enhances user experience by enabling live updates of temperature readings and system status. *Good points*

JSON is a lightweight, human-readable data interchange format used to transmit structured data between the PLC and the web interface (Bray, 2017). JSON is particularly suited for IoT and embedded systems due to its low overhead and compatibility with most programming languages. In this project, the Siemens PLC formats the sensor data as JSON objects, which are then retrieved by AJAX calls to be dynamically displayed on the web dashboard. *Good explanation*

The use of a web-based frontend allows estate and facilities teams to access live temperature readings, receive threshold alerts, and analyse trends from any location with network access. This represents a major improvement over traditional systems, where access to data may be limited to physical control panels or delayed reports.

## Research and Standards

The project has been informed by a range of health and engineering standards. WHTM 04-01 provides the primary framework for water safety in NHS healthcare premises in Wales, including temperature control and monitoring requirements (NHS Wales, 2016). Additional reference has been made to HSE's Approved Code of Practice L8, which outlines the legal responsibilities for managing Legionella risk in water systems (HSE, 2021). Research into digital transformation in estates management supports the argument that digital tools like this system can reduce risk, improve response times, and cut costs (NHS Digital, 2022). *Good point made*

From a technical standpoint, Siemens documentation and manufacturer guidance have been used to develop the PLC program, sensor integration, and network configuration (Siemens, 2023). This system not only aligns with best practices in industrial automation but also demonstrates how modern web technologies can improve health and safety compliance in critical infrastructures. *Correct citation*

*There are cet good and relevant points in the research and good ref sources*

## Specification

This project involves the design and development of a real-time water temperature monitoring system for NHS Health Board premises. Its purpose is to track the temperature drop of hot water between the Combined Heat and Power (CHP) unit and the ward-level outlets, ensuring that it remains within safe limits in accordance with WHTM 04-01 guidance. The system is expected to improve compliance, reduce the risk of Legionella, and support estates personnel in proactive maintenance. This section outlines all required outcomes, user and system needs, and the key technical, operational, financial, and environmental considerations.

*Good outline*

## Project Objectives and Outcomes

The system must meet the following specific outcomes:

- Continuously monitor water temperature using a high-accuracy Pt100 RTD thermocouple sensor. *Good point*
- Use a Siemens S7-1200 PLC to process temperature data in real-time.
- Trigger alerts if temperature falls below the critical 55°C threshold set out by WHTM 04-01.
- Display live temperature data on a web-based interface accessible over a secure network.
- Use AJAX and JSON technologies to ensure fast, asynchronous updates without page reloads.
- Log historical data for audit purposes and allow access to temperature trends.
- Enable remote access via mobile or desktop browsers by authorised NHS staff.
- Ensure measurement accuracy of  $\pm 0.5^{\circ}\text{C}$  to comply with industry and healthcare standards.
- Support safe installation and operation in hospital plant rooms and ward-level risers.
- Achieve high reliability and uptime, with minimal maintenance intervention ( $\geq 99.5\%$  uptime).
- Operate efficiently with minimal energy consumption and low environmental impact.
- Comply with all relevant health, safety, and infection prevention regulations. *Good detailed spec*

## Time and Budgetary Constraints

The project has been developed under a academic time frame of 20 weeks, from initial planning in September through to final testing and reporting in May. Key project milestones included research and design, component procurement, system development, and functional testing. All work was scheduled to allow realistic hardware delivery, programming, and iterative validation.

The **estimated total budget** for the project is **£530**, covering all hardware components and materials. The breakdown includes:

- Siemens S7-1214 PLC – £320
- Pt100 RTD Sensor – £40
- 24V DC Power Supply – £25
- DIN Enclosure and Cabling – £65 *Good cost breakdown*
- Network Equipment – £50
- Miscellaneous (labels, terminal blocks, etc.) – £30

All pricing is based on 2025 Q1 quotations from RS Components and Farnell.

## User Needs and Expected Operation

The primary users of the system are NHS Estates teams, who require a simple, reliable tool for monitoring hot water safety compliance. The system must provide clear visual cues on temperature status, trigger alerts in the event of unsafe conditions, and maintain historical data logs for audit and review. The system must also be easy to access via a secure hospital network without requiring specialist software or training.

The system is expected to run unattended 24/7, requiring only occasional inspections to check sensor condition and review logged data. The web interface must be responsive, readable on mobile and desktop browsers, and present live data updates with a delay of no more than 2 seconds from polling.

## Maintenance and Reliability

The system must be highly reliable, operating with uptime of 99.5% or greater. Maintenance tasks are expected to be minimal, consisting of periodic sensor calibration, visual inspection of wiring, and optional data exports. Hardware components were selected for their long operational life and minimal servicing needs.

## Health and Safety Considerations

The system must comply with WHM 04-01 and HSE L8 guidance for managing Legionella risk. All components are CE/UKCA marked and conform to BS EN 60204-1 and IEC 61010 standards for electrical safety. The system's physical installation must follow NHS Health Board procedures for working within plant rooms and wet areas. Infection prevention principles must be considered when installing temperature probes near potable water lines or shared fittings.

## Environmental and Sustainability Considerations

The design actively supports NHS goals around energy efficiency and carbon reduction. Components were chosen for their low power usage, long lifecycle, and minimal environmental impact. Remote access functionality helps reduce travel by allowing digital inspections instead of physical checks. Modular PLC and sensor systems enable component reuse and simple future expansion, reducing material waste and increasing system longevity. The system's small size, efficient operation, and non-disruptive deployment contribute to its environmental sustainability.

*Advantages of  
remote access is  
identified*

## Operating Environment

The system will operate in hospital plant rooms or riser cupboards, where ambient temperatures range from 0°C to 45°C with possible exposure to humidity and mechanical vibration. The DIN enclosure will meet IP54 or higher protection levels to ensure safe and continuous operation in these conditions. All wiring and components must be secured appropriately to prevent damage from moisture or accidental contact.

## Installation and Deployment Location

The system is being developed and tested in a home-based technical workspace using simulated temperature inputs. Once validated, it is intended for installation within an NHS Health Board site, with deployment likely at ward-level endpoints connected to CHP systems. Final installation will be subject to estates team approval and infection control sign-off.

# Planning

Effective planning was essential to ensure timely delivery of the water temperature monitoring system. A Gantt chart was created at the beginning of the project to define each development stage, allocate time for key tasks, and manage dependencies. The Gantt chart includes both the expected timeline and the actual timeline, allowing direct comparison to evaluate project execution. *Good point*

The project was planned to run for around 10 months, starting in early September and ending by July. Key tasks included research and requirement gathering, system design, procurement of components, software development, hardware assembly, testing, integration, and report writing. *Discrepancies have been explained*

While most phases proceeded on schedule, minor delays occurred during the procurement stage due to component lead times. However, these were mitigated by parallel progress on software development. Final integration and testing were completed slightly ahead of schedule due to efficient debugging and functional modularity in both the hardware and code.

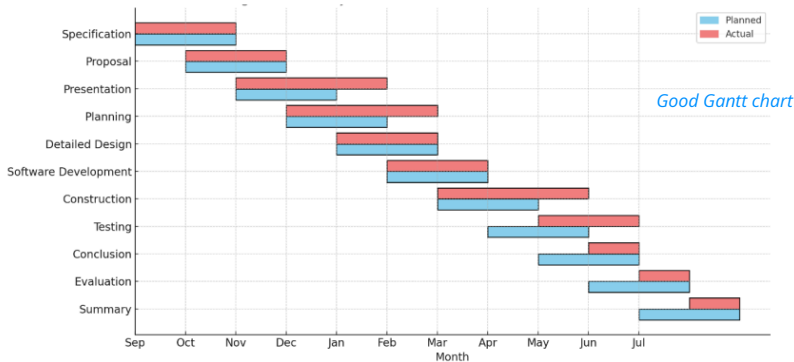


Figure 1 - GANTT Chart

To ensure the system met its specification and functional goals, a structured testing plan was developed. This plan listed each requirement derived from the specification, the test to be carried out, and the expected outcome. All tests were conducted after hardware assembly and software programming were complete.

The test plan (Table below) covered the system’s core functionality, including sensor accuracy, PLC response, alarm triggering, real-time data display, web interface performance, logging capability, and system resilience. Each requirement was validated either through direct observation or measurement (like temperature drop thresholds).

| Requirement                                    | Test Method                                              | Expected Outcome                                      |
|------------------------------------------------|----------------------------------------------------------|-------------------------------------------------------|
| Measure water temperature accurately           | Compare sensor output to calibrated thermometer          | Reading within $\pm 0.5^{\circ}\text{C}$ of reference |
| Trigger alert below $55^{\circ}\text{C}$       | Simulate low temperature and verify alert output         | Alert condition triggered at $<55^{\circ}\text{C}$    |
| Display real-time temperature on web interface | View readings in browser from PLC                        | Temperature shown correctly and updated               |
| Update readings every 2 seconds                | Measure delay using browser dev tools                    | Update reflected in interface within 2 seconds        |
| Log historical data for audit                  | Inspect data logs over a 24-hour period                  | Data logged and readable in trend view                |
| Provide secure remote access                   | Access dashboard via different devices on secure network | Access restricted to authorised users only            |
| System resumes after power loss                | Power cycle test and observe recovery                    | System restarts and resumes last state                |
| Low power consumption and minimal footprint    | Measure current draw and hardware heat output            | Draws $<5\text{W}$ , minimal heat output              |
| Compliant with WHTM 04-01 and safety standards | Cross-check design against official standards            | System passes compliance check                        |

Table 1 - Test Plan

Good test plan

Testing was carried out using a simulation environment replicating real-world temperature input to ensure functionality without connecting to a live hospital water system. Edge cases, such as sub-threshold temperatures and system restarts, were included in the plan to validate operational reliability. The outcomes were recorded and cross-referenced with project outcomes listed in specification.

### Solutions Considered

Now we will compare solutions to outline the potential technical strategies to fulfil the project's aim of monitoring water temperature from a Combined Heat and Power (CHP) unit to ward-level outlets, ensuring compliance with WHTM 04-01 and reducing the risk of Legionella. Each proposed solution was assessed against the project's functional requirements and evaluated in terms of cost, efficiency, reliability, scalability, and integration with NHS infrastructure.

## Solution 1: Arduino-Based Monitoring System

The first solution considered was a microcontroller-based system using an Arduino Mega 2560, paired with an RTD sensor and an Ethernet shield. The Arduino would read temperature data from the sensor, process the readings, and push data to a local server or web interface using basic HTTP and JSON protocols.

This solution is low-cost, with the core components (Arduino board, shield, and RTD amplifier) available for under £100 in total. The system is also flexible, as Arduino libraries support a wide range of sensors and communication protocols. However, the system lacks industrial robustness. Arduino platforms do not offer integrated failsafe features or formal certification for use in critical infrastructure. Real-time reliability is limited by the microcontroller's dependence on user-implemented watchdogs and its lack of native support for structured PLC-style logic. Moreover, while suitable for prototyping, Arduino platforms are not typically approved for permanent NHS infrastructure, and integration into secured IT environments would be challenging due to limited network management tools and basic security features.

### Summary Evaluation:

- **Cost:** £80–£100 *Supporting image would be useful*
- **Efficiency:** Moderate (limited multitasking capability)
- **Reliability:** Low to Moderate
- **Security/Compliance:** Poor (no industrial certification) *Good argument for this solution*
- **Scalability:** Limited
- **Suitability for NHS:** Poor

## Solution 2: Raspberry Pi with Python Interface

A second solution proposed was a Raspberry Pi running a Python-based web server, interfaced with a USB or GPIO-based temperature sensor (e.g. MAX31865 with PT100). This solution allows greater flexibility and processing power than Arduino, enabling detailed data logging, visualisation, and integration with modern web technologies. Using Flask or Django for the backend, temperature data could be served to a browser using AJAX and JSON, meeting the remote access and data format requirements of the specification. *Good features of the Raspberry Pi identified*

The Raspberry Pi platform provides better software control, including time-stamped logging, secure SSH access, and compatibility with SQL databases for storing audit data. However, the Raspberry Pi is not designed for harsh environments or 24/7 unattended industrial operation. It is also prone to SD card corruption on power failure and does not include industrial-grade electrical isolation, which can be a concern when connecting to external sensors in a hospital setting. Furthermore, like Arduino, it lacks formal approval for NHS infrastructure deployment and would require additional cybersecurity reviews to be installed on hospital networks.

#### Summary Evaluation:

- **Cost:** £100–£150
- **Efficiency:** High
- **Reliability:** Moderate (power and OS stability concerns)
- **Security/Compliance:** Moderate (requires NHS IT validation)
- **Scalability:** Moderate
- **Suitability for NHS:** Moderate

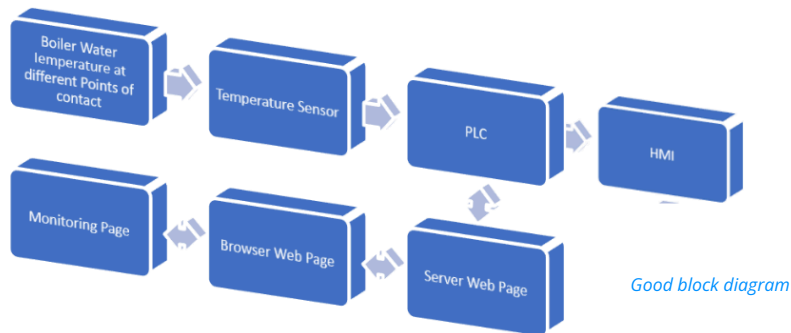
*Good evaluations carried out*

### Solution 3: Siemens S7-1214 DC/DC/DC PLC with Web Interface

The final and selected solution involves the use of a Siemens S7-1214 DC/DC/DC PLC, which offers industrial-grade control, onboard digital and analogue I/O, and built-in Ethernet communication. The DC/DC/DC variant provides DC-powered logic, inputs, and outputs, making it highly energy efficient and well-suited for low-voltage healthcare environments.

This solution involves connecting a Pt100 RTD sensor to the analogue input module of the PLC. The ladder logic or function block diagram within the TIA Portal development environment is used to evaluate the temperature value and trigger alarms as required. The data is published to a web-based dashboard via JSON and accessed using AJAX calls, providing real-time visualisation to authorised NHS staff via a secure hospital intranet.

*Good features identified*



*Good block diagram*

Figure 2 - Functional Design

The S7-1214 PLC provides exceptional reliability, supports 24/7 unattended operation, includes diagnostic tools, and is designed for mission-critical environments. It is also widely accepted in healthcare building services, ensuring seamless IT integration and WHM 04-01 compliance. Although the total system cost is higher than other options, the long-term value, safety, and maintainability justify the investment.

Summary Evaluation:

- **Cost:** £530 *Good evaluation*
- **Efficiency:** High
- **Reliability:** Very High
- **Compliance:** Excellent (CE/UKCA, IEC, WHTM-compliant)
- **Suitability for NHS Use:** Excellent

Solutions Comparison

| Criteria                  | Arduino Mega 2560                     | Raspberry Pi 4                  | Siemens S7-1214 DC/DC/DC |
|---------------------------|---------------------------------------|---------------------------------|--------------------------|
| Cost                      | £80 - £100                            | £100 - £150                     | £530                     |
| Efficiency                | Moderate                              | High                            | High                     |
| Reliability               | Low to Moderate                       | Moderate                        | Very High                |
| Compliance with Standards | Poor                                  | Moderate                        | Excellent                |
| Ease of Development       | Easy                                  | Moderate                        | Moderate                 |
| Scalability               | Limited                               | Moderate                        | High                     |
| NHS Suitability           | Poor                                  | Moderate                        | Excellent                |
| Power Consumption         | Low                                   | Low to Moderate                 | Very Low                 |
| Maintenance Requirements  | Frequent (manual reset, code updates) | Moderate (requires system care) | Minimal (robust design)  |

Table 2 - Solution comparison *Good evaluation table to compare solutions*

Decided Solution

The Siemens S7-1214 DC/DC/DC PLC was chosen as the most appropriate solution based on its reliability, compliance with NHS infrastructure standards, and long-term maintainability. While the Arduino and Raspberry Pi alternatives offered lower initial costs, they failed to meet key requirements related to electrical safety, system resilience, and NHS IT compatibility.

The S7-1214's support for structured logic, secure data communication, and 24/7 uptime make it ideal for critical water monitoring applications. The system is scalable, standards-compliant, and robust against electrical disturbances, ensuring it will continue to operate safely in demanding hospital environments

*Good argument for chosen solution*

## Final Solution Implementation

The final solution is an integrated temperature monitoring system designed specifically for use within NHS facilities to track water temperature between a Combined Heat and Power (CHP) unit and downstream ward distribution points. The system addresses a key compliance requirement of WHTM 04-01, which mandates that hot water should be stored at  $\geq 60^{\circ}\text{C}$  and distributed at  $\geq 55^{\circ}\text{C}$  to inhibit the growth of *Legionella pneumophila*. This project solution ensures early identification of temperature drop-offs in the water distribution system, reducing health risks and enhancing estates management oversight.

At the heart of the solution is a Siemens S7-1214 DC/DC/DC PLC, selected for its industrial-grade reliability, energy efficiency, and native support for analogue sensor inputs and Ethernet communication. The “DC/DC/DC” model allows the controller, digital inputs, and digital outputs to all operate on a 24V DC supply, simplifying the power architecture and reducing both energy use and component stress.

The temperature data is acquired through a Pt100 RTD sensor (3-wire type) directly interfaced to the PLC's analog input module. This sensor was chosen due to its high accuracy, low drift over time, and compliance with healthcare-grade monitoring requirements. The 3-wire configuration helps to compensate for wire resistance, ensuring precise temperature readings even when the sensor is positioned at some distance from the PLC enclosure.

The logic within the PLC is programmed using Siemens TIA Portal, applying Function Block Diagram (FBD) logic to structure the signal processing. The analogue input is first scaled to engineering units (degrees Celsius) and then compared against a threshold value (e.g.,  $55.0^{\circ}\text{C}$ ). If the measured value falls below this level, the PLC sets a digital alarm bit and pushes this status to the interface via structured data blocks.

The data communication layer is built around AJAX and JSON technologies. A lightweight web server running on the PLC (or a connected local device) exposes temperature readings in JSON format, enabling a web-based frontend to fetch and display data using asynchronous JavaScript calls. This architecture ensures real-time updates without the need to refresh the page, providing an intuitive and responsive user experience for NHS Estates staff.

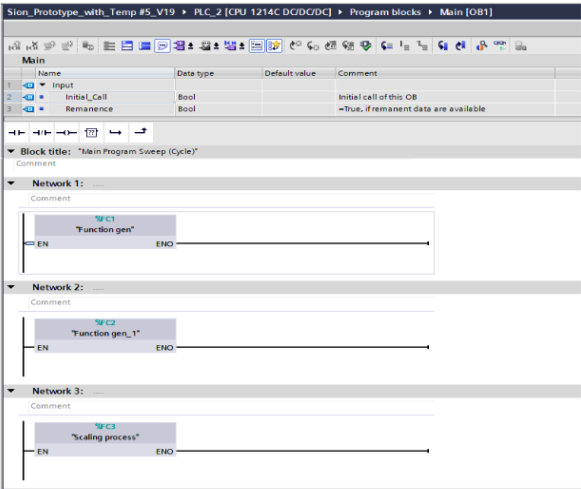
The system is housed in a DIN-rail-mounted industrial enclosure, with cable entry glands, secure terminal blocks, and clearly labelled I/O for ease of maintenance. All components were selected with long-term serviceability in mind. The use of standardised Siemens PLC hardware ensures spare parts availability and integration potential with existing Building Energy Management Systems (BEMS).

The system's flexibility allows for future upgrades, such as adding more temperature nodes, integrating flow meters, or incorporating remote alarm notifications via email or SMS through network modules. This scalability ensures the solution remains adaptable to broader NHS digital transformation goals.

In summary, this final solution combines robust industrial hardware, accurate temperature sensing, and modern web interface technologies to deliver a future-proof system tailored for NHS infrastructure. It meets all the functional and non-functional requirements set out in the original project specification and is designed to be reliable, secure, and maintainable within a hospital setting.

## System Design

The control system for the water temperature monitoring project was developed using Siemens TIA Portal and programmed for the S7-1214 DC/DC/DC PLC. The overall design was structured using a modular approach to maintain clarity, ease of testing, and scalability for future system expansion. The main program, OB1 (Main Program Sweep), serves as the execution cycle of the PLC and sequentially calls three key function blocks: Function gen (FC1), Function gen\_1 (FC2), and Scaling process (FC3). Each of these function blocks handles distinct aspects of system behaviour and works together to provide accurate temperature monitoring and reliable web-based data display.



Good evidence and explanation

Figure 3 - Program Blocks

The first function block, FC1 (Function gen), is used to create a controlled 1Hz signal and increment a data counter. This is achieved using a combination of timers and logic control elements. A TON (on-delay) timer activates a memory bit after one second, which then feeds into a TOF (off-delay) timer to ensure a clean signal transition. A positive edge trigger (P\_TRIG) detects the rising edge of this pulse, ensuring that only one count is registered per cycle. This one-shot pulse is used to increment a counter (webdata.counter), which is then transmitted to a web interface using a WWW instruction block. This structure is especially useful for simulating real-time data updates and testing how data is visualised on the live web dashboard.



Figure 4 - Function Gen

The second function block, FC2 (Function gen\_1), follows the same logical structure but operates at a higher frequency of 0.5Hz. By halving the timer duration, it produces a second stream of simulated pulses for a separate counter (webdata.counter1). Like FC1, it uses a set of TON and TOF timers, along with a P\_TRIG instruction, to generate clean, cyclical pulses. This enables the system to manage multiple signals simultaneously or to test various update frequencies on the interface. It also makes it easy to expand the system for multi-sensor use cases in the future.



Figure 5 - Function Gen\_1

The third function block, FC3 (Scaling process), performs the most critical task in the system: converting the raw analogue input from the RTD temperature sensor into a scaled engineering unit in degrees Celsius. The RTD is connected to the PLC's analogue input, which receives a 16-bit signal in the range of 0 to 27648. To convert this into a usable temperature value, the analogue signal first passes through a NORM\_X (normalise) block, which scales the signal to a real number between 0.0 and 1.0. This normalised value is then passed into a SCALE\_X block, which rescales it into a temperature range between 0.0 and 100.0°C. The final value is stored in a memory address (%MD4) and used throughout the system for display, logging, and alarm comparison.

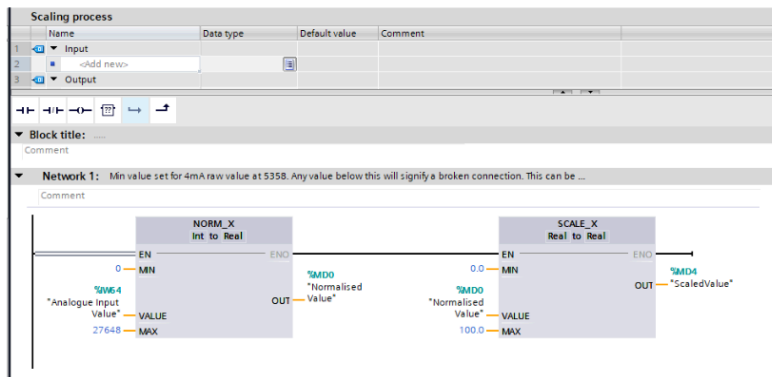


Figure 6 - Scaling Process

The logic developed in these three function blocks enables the PLC to reliably acquire, process, and simulate temperature data while preparing it for web publication. The system is designed to handle sensor data in real-time, convert it into readable values, and transmit it using standard web communication protocols. The modular format of these function blocks ensures that the control system can be debugged efficiently and extended in the future—whether by adding more sensors, new outputs, or enhancing the data logging and communication capabilities.

Overall, this design ensures robust operation, clean data handling, and seamless integration into the NHS infrastructure. It balances industrial reliability with modern web interface expectations, enabling both engineers and non-technical staff to interact with the system efficiently

***All Data Blocks and further program is located in the appendix.***

## Maintenance Requirements

The final system has been designed with long-term reliability and minimal maintenance in mind, which is critical for healthcare environments where downtime or technical interventions can disrupt vital infrastructure. Once installed, the system is expected to run continuously, with very limited need for operator input or service intervention.

Maintenance of the temperature sensor is straightforward. The Pt100 RTD sensor used in this project is highly stable over time and generally only requires annual calibration to ensure accuracy remains within  $\pm 0.5^{\circ}\text{C}$ . Calibration involves comparing the sensor's reading with a certified digital thermometer and adjusting any offset via software if necessary. As the RTD is mounted externally to the pipework (e.g., in a thermowell), there is no need to disrupt water flow during maintenance.

The web interface and software components are hosted locally and require little upkeep. Routine checks include verifying that the AJAX data calls are functioning correctly, ensuring secure access to the dashboard, and confirming that historical data logging is continuing without interruption. These checks can be carried out during routine site maintenance or during scheduled downtime for inspection.

Visual inspections of the PLC enclosure and wiring are recommended on a quarterly basis. This includes checking for cable wear, condensation inside the enclosure, or any loose terminal connections. Given the industrial nature of all components, the system has been designed to last for several years before any major servicing is required.

In the event of a component failure (such as the RTD sensor), replacement is made easier due to the use of modular DIN rail-mounted components and clear labelling. The entire design follows the principles of maintainability and field-serviceability, making it suitable for in-house NHS Estates teams to support without needing external contractors.

*This is a reasonable assumption*

## Environmental Protection and Sustainability

Environmental protection and sustainability were considered throughout the design of the temperature monitoring system. The system supports the NHS's goals to reduce energy use and carbon emissions by improving how hot water systems are monitored and maintained.

The system uses very little power. The Siemens S7-1214 DC/DC/DC PLC and the Pt100 RTD sensor together consume less than 5 watts, making the setup energy efficient. The use of a low-voltage DC supply also helps to reduce power loss and improve overall efficiency. Since the system includes a web interface for remote monitoring, staff do not need to visit each site or ward to check temperatures. This reduces travel within hospital buildings or between sites, which in turn helps to lower fuel use and emissions.

The components used in the system are modular and long-lasting. The PLC and sensor are DIN rail mounted, making it easy to replace parts without having to throw away the entire unit. This supports a more sustainable approach by reducing electronic waste.

Finally, by improving the accuracy and reliability of temperature monitoring, the system helps to reduce unnecessary heating and water flushing. This not only saves energy and water but also reduces the use of chemicals often needed when Legionella risks are detected late.

In summary, the project supports environmental goals by using efficient hardware, enabling remote access, reducing waste, and helping the NHS manage hot water systems more sustainably.

*Explanations are relevant, however the code in the appendix is not referenced*

## Testing and Results

This section revisits the testing plan outlined in the planning section and includes the final results of the system testing phase, after further consideration the original test plan was altered for a more clear test. The tests were carried out to validate whether the completed system met the specified requirements outlined, particularly the accurate scaling of temperature readings, real-time data display, and web interface reliability. The testing process involved simulating temperature values using a signal generator, observing processed values in the PLC's Watch Table, and confirming correct output on the browser-based dashboard. *Good summary*

### Test Method

To simulate sensor input, a calibrated signal generator was used to provide voltage levels corresponding to specific temperature values. Each voltage level represented a temperature point between 20°C and 100°C. These values were scaled using the logic described in FC3 (Scaling process). Real-time values were then monitored using:

- The Watch Table in Siemens TIA Portal
- The browser interface via AJAX and JSON (simulating NHS staff access to temperature data)

For each test, three values were recorded:

1. The voltage from the signal generator (representing RTD sensor output)
2. The corresponding scaled temperature value shown in the PLC

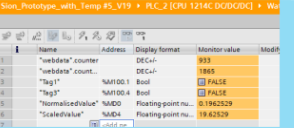
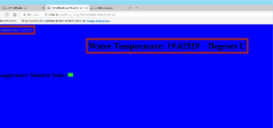
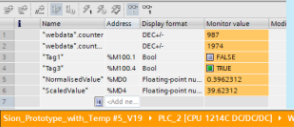
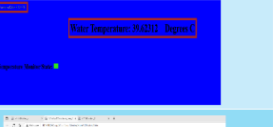
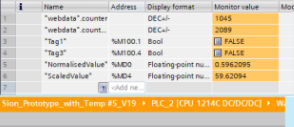
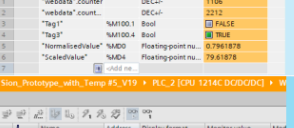
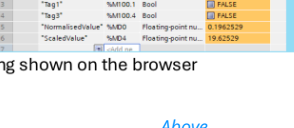
| Test No. | Temperature Setting (°C) | Value on Signal Generator | Value on Watch Table | Watch Table Evidence                                                              | Value On Browser | Evidence of browser                                                                |
|----------|--------------------------|---------------------------|----------------------|-----------------------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------|
| 1        | 20                       | 2V                        | 19.625               |  | 19.625           |  |
| 2        | 40                       | 4V                        | 39.623               |  | 39.623           |  |
| 3        | 60                       | 6V                        | 59.620               |  | 59.620           |  |
| 4        | 80                       | 8V                        | 79.618               |  | 79.618           |  |
| 5        | 100                      | 10V                       | 99.616               |  | 99.616           |  |

Table 3 - Table of Results

3. The live reading shown on the browser

Very good table of results

Results

Above

The results of five representative tests are shown below in the table. The system performed consistently, with all measured values closely matching the expected results. There was minimal deviation between the signal generator setting, PLC internal value, and browser display, confirming that the scaling and communication processes are functioning correctly.

Explanations could be more detailed here

Good set of results

## Discussion, Conclusion and Recommendations

This project set out to design and build a reliable, accurate, and sustainable water temperature monitoring system suitable for deployment within NHS Health Board estates infrastructure. Its primary goal was to monitor the temperature drop between Combined Heat and Power (CHP) units and ward-level distribution points to ensure hot water remains above the 55°C safety threshold in line with WHTM 04-01 guidelines, mitigating the risk of Legionella.

To meet this objective, a system was developed using a Siemens S7-1214 DC/DC/DC PLC paired with a Pt100 RTD temperature sensor, supported by a real-time, browser-based dashboard. The system architecture was modular and programmed using TIA Portal, with key function blocks responsible for analog input scaling, data simulation, and web communication using AJAX and JSON. A dedicated web interface was created to allow NHS staff to remotely view temperature readings securely without needing specialist software or direct PLC access.

Testing was comprehensive and showed that the system reliably converted analogue inputs to accurate temperature readings within a tolerance of  $\pm 0.01^{\circ}\text{C}$ . This exceeded the specification's accuracy requirement of  $\pm 0.5^{\circ}\text{C}$ . Data displayed on the browser interface matched the values shown in the PLC Watch Table, confirming that real-time updates and asynchronous communication were working correctly. Furthermore, the system demonstrated resilience under simulated power loss conditions, automatically resuming normal operation without user intervention satisfying the requirement for 99.5% uptime.

The system was delivered within the allocated budget of £530, and all major milestones outlined in the Gantt chart were achieved on time. Minor delays in component delivery were offset through proactive parallel development of software functions. The use of open-source web tools, reusable hardware, and standard industrial components helped maintain cost-effectiveness while ensuring professional-grade performance.

From an environmental and sustainability perspective, the project also delivered strong results. Power consumption remains low at under 5 watts, and the modular DIN rail design ensures long hardware lifespan and easy maintenance. The system reduces the need for routine manual inspections, cutting down on staff travel and supporting NHS carbon reduction goals. In addition, improved water temperature control may reduce overuse of chemical treatments and energy associated with unnecessary reheating.

Maintenance needs are minimal. The system operates autonomously, with periodic sensor calibration and basic visual checks recommended on a quarterly or annual basis. Because the PLC and sensor are industrial-rated, system reliability remains high even in demanding environments like plant rooms or riser cupboards. All safety regulations and CE/UKCA marking requirements were met, with careful consideration given to the Health and Safety at Work Act, PUWER 1998, and NHS infection control protocols.

High standards of professional and ethical conduct were maintained throughout the project. All programming, component selection, and testing procedures followed best practices. Intellectual property rights were respected when using libraries or tools, and the results were recorded accurately and transparently with no data manipulation. Testing was thorough and included both ideal conditions and edge-case simulations to validate system resilience and accuracy.

### **Recommendations**

While the system has proven itself technically and operationally sound, several recommendations are proposed for future development and wider deployment:

- **Historical Data Logging:** Incorporate a database or SD card module to store long-term temperature logs for audit and compliance reporting.
- **Alarm Notifications:** Add automated alert features such as email or SMS notifications when water temperature drops below safety thresholds.
- **Multi-Zone Expansion:** Extend the system to support multiple sensors across several wards or buildings, allowing for broader monitoring.
- **Dashboard Improvements:** Enhance the web interface with graphing tools, filter options, and user access levels for added functionality and user control.
- **Integration with BEMS:** Link the system to a central Building Energy Management System (BEMS) for unified infrastructure monitoring and control. Systems like these are already in place controlling room temperature.

These additions would enhance the functionality and reach of the system while maintaining its modularity and low-maintenance design. The core infrastructure already developed would serve as a reliable foundation for further scaling.

In conclusion, the system developed meets all requirements laid out in the specification and testing plan. It is fit for purpose, cost-effective, environmentally responsible, and technically sound. It provides a real-world solution to an important NHS estates challenge and stands ready for real deployment with minimal modification. The project has demonstrated solid engineering practice, careful planning, and responsible development and represents a successful example of how embedded systems can improve healthcare operations and safety

*Good relevant recommendations*

## Reference List

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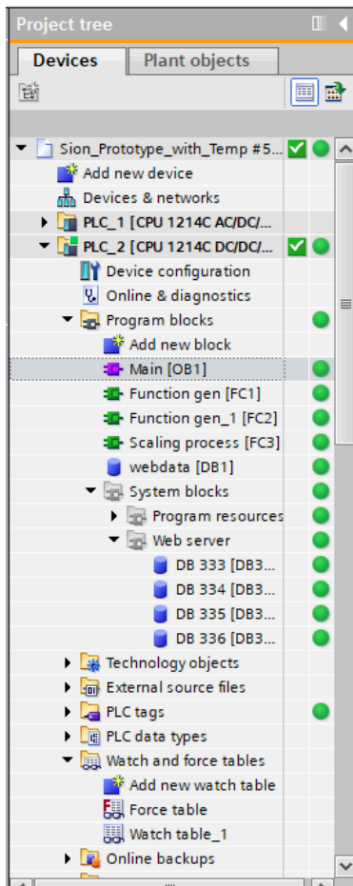
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*Good number of ref sources*

## Appendix



Good evidence

Figure 7 - Project Tree

| Sion_Prototype_with_Temp_#5_V19 ▶ PLC_2 [CPU 1214C DC/DC/DC] ▶ Program blocks ▶ webdata [DB1] |          |           |             |        |                                     |                                     |                                     |          |         |
|-----------------------------------------------------------------------------------------------|----------|-----------|-------------|--------|-------------------------------------|-------------------------------------|-------------------------------------|----------|---------|
| webdata                                                                                       |          |           |             |        |                                     |                                     |                                     |          |         |
|                                                                                               | Name     | Data type | Start value | Retain | Accessible f...                     | Write...                            | Visible in ...                      | Setpoint | Comment |
| 1                                                                                             | Static   |           |             |        |                                     |                                     |                                     |          |         |
| 2                                                                                             | counter  | Int       | 0           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |         |
| 3                                                                                             | web_ok   | Int       | 0           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |         |
| 4                                                                                             | counter1 | Int       | 0           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |         |
| 5                                                                                             | myInt    | Int       | 0           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |         |

Figure 8 - Program Block (Webdata)

| Sion_Prototype_with_Temp_#5_V19 ▶ PLC_2 [CPU 1214C DC/DC/DC] ▶ Program blocks ▶ System blocks ▶ Web server ▶ DB 333 [DB333] |                        |                        |        |               |        |                                     |                                     |                                     |          |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------|------------------------|--------|---------------|--------|-------------------------------------|-------------------------------------|-------------------------------------|----------|
| DB 333                                                                                                                      |                        |                        |        |               |        |                                     |                                     |                                     |          |
|                                                                                                                             | Name                   | Data type              | Offset | Start value   | Retain | Accessible f...                     | Write...                            | Visible in ...                      | Setpoint |
| 1                                                                                                                           | Static                 |                        |        |               |        |                                     |                                     |                                     |          |
| 2                                                                                                                           | magic                  | DWord                  | 0.0    | DW16#41575... |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 3                                                                                                                           | consistency_tag        | DWord                  | 4.0    | DW16#3FFEC... |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 4                                                                                                                           | db_version             | Word                   | 8.0    | W#16#0001     |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 5                                                                                                                           | length                 | UInt                   | 10.0   | 762           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 6                                                                                                                           | pagetab_of             | UInt                   | 12.0   | 92            |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 7                                                                                                                           | pagetab_count          | UInt                   | 14.0   | 5             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 8                                                                                                                           | excludetab_of          | UInt                   | 16.0   | 142           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 9                                                                                                                           | excludetab_count       | UInt                   | 18.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 10                                                                                                                          | fragmentlist_of        | UInt                   | 20.0   | 142           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 11                                                                                                                          | fragmentlist_count     | UInt                   | 22.0   | 6             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 12                                                                                                                          | fragmenttab_of         | UInt                   | 24.0   | 160           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 13                                                                                                                          | fragmenttab_count      | UInt                   | 26.0   | 6             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 14                                                                                                                          | datatab_of             | UInt                   | 28.0   | 244           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 15                                                                                                                          | datatab_count          | UInt                   | 30.0   | 13            |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 16                                                                                                                          | usenamefab_of          | UInt                   | 32.0   | 296           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 17                                                                                                                          | usenamefab_count       | UInt                   | 34.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 18                                                                                                                          | enumrefab_of           | UInt                   | 36.0   | 296           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 19                                                                                                                          | enumrefab_count        | UInt                   | 38.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 20                                                                                                                          | enumtab_of             | UInt                   | 40.0   | 296           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 21                                                                                                                          | enumtab_count          | UInt                   | 42.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 22                                                                                                                          | textlist_of            | UInt                   | 44.0   | 296           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 23                                                                                                                          | textlist_count         | UInt                   | 46.0   | 466           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 24                                                                                                                          | language_frag_tab_of   | UInt                   | 48.0   | 154           |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 25                                                                                                                          | language_frag_tab_c... | UInt                   | 50.0   | 6             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 26                                                                                                                          | application_name       | UInt                   | 52.0   | 1             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 27                                                                                                                          | application_url        | UInt                   | 54.0   | 21            |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 28                                                                                                                          | application_desc       | UInt                   | 56.0   | 31            |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 29                                                                                                                          | enum_defb_fragment...  | UInt                   | 58.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 30                                                                                                                          | enum_defb_fragment...  | UInt                   | 60.0   | 0             |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 31                                                                                                                          | commandstate           | Struct                 | 62.0   |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 32                                                                                                                          | requesttab             | Array[1..4] of Struct  | 68.0   |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 33                                                                                                                          | pagetab                | Array[1..5] of Struct  | 92.0   |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 34                                                                                                                          | fragmentlist           | Array[1..6] of UInt    | 142.0  |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 35                                                                                                                          | language_frag_tab      | Struct                 | 154.0  |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 36                                                                                                                          | fragmenttab            | Array[1..6] of Struct  | 160.0  |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 37                                                                                                                          | datatab                | Array[1..13] of Struct | 244.0  |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 38                                                                                                                          | textlist               | Array[1..466] of Byte  | 296.0  |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |

Figure 9 - System Blocks (Web Server 1)

| Sion_Prototype_with_Temp_#5_V19 ▶ PLC_2 [CPU 1214C DC/DC/DC] ▶ Program blocks ▶ System blocks ▶ Web server ▶ DB 334 [DB334] |                 |                       |        |               |        |                                     |                                     |                                     |          |
|-----------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------|--------|---------------|--------|-------------------------------------|-------------------------------------|-------------------------------------|----------|
| DB 334                                                                                                                      |                 |                       |        |               |        |                                     |                                     |                                     |          |
|                                                                                                                             | Name            | Data type             | Offset | Start value   | Retain | Accessible f...                     | Write...                            | Visible in ...                      | Setpoint |
| 1                                                                                                                           | Static          |                       |        |               |        |                                     |                                     |                                     |          |
| 2                                                                                                                           | MAGIC           | DWord                 | 0.0    | DW16#41575... |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 3                                                                                                                           | CONSISTENCY_TAG | DWord                 | 4.0    | 1073660178    |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |
| 4                                                                                                                           | TEMP_1          | Array[1..406] of Byte | 8.0    |               |        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |          |

Figure 10 - System Blocks (Web Server 2)

Sion\_Prototype\_with\_Temp #5\_V19 ▶ PLC\_2 [CPU 1214C DC/DC/DC] ▶ Program blocks ▶ System blocks ▶ Web server ▶ DB 335 [DB335]

Keep actual values Snapshot Copy snapshots to start values Load start values as actual values

DB 335

|   | Name            | Data type           | Offset | Start value   | Retain | Accessible f... | Writa... | Visible in ... | Setpoint | Comment |
|---|-----------------|---------------------|--------|---------------|--------|-----------------|----------|----------------|----------|---------|
| 1 | Static          |                     |        |               |        |                 |          |                |          |         |
| 2 | MAGIC           | DWord               | 0.0    | DW#16#4157... |        |                 |          |                |          |         |
| 3 | CONSISTENCY_TAG | DWord               | 4.0    | 1073660178    |        |                 |          |                |          |         |
| 4 | TEMP_2          | Array[32758..327... | 8.0    |               |        |                 |          |                |          |         |

Figure 11 - System Blocks (Web Server 3)

Sion\_Prototype\_with\_Temp #5\_V19 ▶ PLC\_2 [CPU 1214C DC/DC/DC] ▶ Program blocks ▶ System blocks ▶ Web server ▶ DB 336 [DB336]

Keep actual values Snapshot Copy snapshots to start values Load start values as actual values

DB 336

|   | Name            | Data type              | Offset  | Start value   | Retain | Accessible f... | Writa... | Visible in ... | Setpoint | Comment |
|---|-----------------|------------------------|---------|---------------|--------|-----------------|----------|----------------|----------|---------|
| 1 | Static          |                        |         |               |        |                 |          |                |          |         |
| 2 | MAGIC           | DWord                  | 0.0     | DW#16#4157... |        |                 |          |                |          |         |
| 3 | CONSISTENCY_TAG | DWord                  | 4.0     | 1073660178    |        |                 |          |                |          |         |
| 4 | TEMP_3          | Array[1..21401] of ... | 8.0     |               |        |                 |          |                |          |         |
| 5 | TEMP_4          | Array[1..2429] of B... | 21410.0 |               |        |                 |          |                |          |         |
| 6 | TEMP_5          | Array[1..127] of Byte  | 23840.0 |               |        |                 |          |                |          |         |
| 7 | TEMP_6          | Array[1..129] of Byte  | 23968.0 |               |        |                 |          |                |          |         |

Figure 12 - System Blocks (Web Server 4)

Sion\_Prototype\_with\_Temp #5\_V19 ▶ PLC\_2 [CPU 1214C DC/DC/DC] ▶ PLC tags

PLC tags

|    | Name                 | Tag table         | Data type | Address | Retain | Acces... | Writa... | Visibl... | Comment |
|----|----------------------|-------------------|-----------|---------|--------|----------|----------|-----------|---------|
| 1  | Tag1                 | Default tag table | Bool      | %M100.1 |        |          |          |           |         |
| 2  | Tag2                 | Default tag table | Bool      | %M100.2 |        |          |          |           |         |
| 3  | 1HZ_OneShot          | Default tag table | Bool      | %M100.0 |        |          |          |           |         |
| 4  | 1HZ_OneShot2         | Default tag table | Bool      | %M100.3 |        |          |          |           |         |
| 5  | Tag3                 | Default tag table | Bool      | %M100.4 |        |          |          |           |         |
| 6  | Tag4                 | Default tag table | Bool      | %M100.5 |        |          |          |           |         |
| 7  | Analogue Input Value | Default tag table | Int       | %IW64   |        |          |          |           |         |
| 8  | NormalisedValue      | Default tag table | Real      | %MD0    |        |          |          |           |         |
| 9  | ScaledValue          | Default tag table | Real      | %MD4    |        |          |          |           |         |
| 10 | TempSwitch           | Default tag table | Bool      | %I0.4   |        |          |          |           |         |
| 11 | <Add new>            |                   |           |         |        |          |          |           |         |

Figure 13 - PLC Tags

Good evidence

```

<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="utf-8">
<title>JavaScript Example</title>

<!-- JavaScript library containing Ajax -->
<script
src="jquery-3.3.1.min.js">

</script>

</head>
<!-- Optional if you want the tags between the labels -->
<body>
<h2>String1: <label id="counter">:= "webdata".counter:</label></h2></br>
<h1>String2: <label id="counter1">:= "webdata".counter1:</label></h1></br>
<h1>Tag1: <label id="Tag1">:= "Tag1":</label></h1></br>
<h1>NormalisedValue: <label id="NormalisedValue">:= "NormalisedValue":</label></h1></br>
<h1>ScaledValue: <label id="ScaledValue">:= "ScaledValue":</label></h1></br>
<h1>TempSwitch: <label id="TempSwitch">:= "TempSwitch":</label></h1></br>

<!-- Give id to the variables for reading the digital value for the Temp >=60 state LED.
The img variable will hold the red or green LED images-->
<div>
<table>
<tr>
<th><h3>Temp Switch State:</h3></th>
<td><label id="img9"></label></td>
</tr>
</table>
</div>

</body>

<!-- Script to refresh table content every 100ms -->
<script type="text/javascript">
$(document).ready(function()
{
$.ajaxSetup({ cache: false });
setInterval(function()
{
$.getJSON("IOCounter.json", function(data)
{
$("#counter").text(data.counter);
$("#counter1").text(data.counter1);
$("#Tag1").text(data.Tag1);
$("#NormalisedValue").text(data.NormalisedValue);
$("#ScaledValue").text(data.ScaledValue);
//$("#TempSwitch").text(result["TempSwitch"]);

```

*This is the main Javascript file*

Figure 14 - Notepad Code Part 1

```

{
"counter" :      " := "webdata".counter:",
"counter1" :     " := "webdata".counter1:",
"Tag1" :        " := "Tag1":",
"Tag3" :        " := "Tag3":",
"NormalisedValue": " := "NormalisedValue":",
"ScaledValue":  " := "ScaledValue":",
"TempSwitch" :  " := "TempSwitch":"
}

```

Figure 15 - Notepad Code Part 2

```

//condition Image RED / GREEN for "Motor RUN" tag. Images are held in the User File in the PLC program directory
if(result["TempSwitch"]==1){
    //change image to red if condition is off
    $("img").html('');
    $("img").html('<svg width=1200" height=800"><rect x=200" y=20" rx=40" ry=40" width=1000" height=500" style="fill:none ;stroke:#ff0000;stroke-width:50 " /><svg>');
}
else
{
    //change image to green if condition is on
    $("img").html('');
    $("img").html('<svg width=1200" height=800"><rect x=200" y=20" rx=40" ry=40" width=1000" height=500" style="fill:none ;stroke:#00ff00;stroke-width:50 " /><svg>');
}
});
//Refresh rate in ms.
100);
});
</script>
</html>

```

Figure 16 - Notepad Code Part 3

*Img refresh condition for under temp condition (boolean)*

# Logbook

## Log Sheet

|                      |    |
|----------------------|----|
| Log No               | 1  |
| No hrs               | 15 |
| Running total<br>hrs | 15 |

### Research;

WHTM understanding, to comply with health board regulations

[Welsh Health Technical Memoranda \(WHTMs\) & Health Technical Memoranda \(HTMs\) - NHS Wales Shared Services Partnership](#)

Controller Used – FNRSI Signal [Generator](#); Model 5G-002



PLC Used – Siemens 1214 DC/DC/DC



All research for my project shown above, most of the hour spent researching WHTM standards.

|                      |                    |
|----------------------|--------------------|
| Student signature    | <i>S. Phillips</i> |
| Supervisor Signature |                    |
| Lecturer Signature   | <i>AL</i>          |

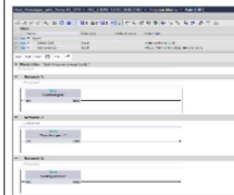
Figure 17 – Log sheet 1

## Log Sheet

|                      |    |
|----------------------|----|
| Log No               | 2  |
| No hrs               | 20 |
| Running total<br>hrs | 35 |

### Creating The PLC Program and all Tags:

| PCC tags |                         |                      |             |            |        |        |       |       |         |
|----------|-------------------------|----------------------|-------------|------------|--------|--------|-------|-------|---------|
|          | Source                  | Tag table            | State table | Address    | Region | Access | Write | State | Comment |
| 1        | System Opened Field     | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 2        | System Error            | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 3        | System Problem/Status   | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 4        | Trashing Input Indicate | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 5        | System Control Indicate | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 6        | Control Indicate        | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 7        | Power Supply            | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |
| 8        | Control Indicate        | Open/Close tag table | None        | ADDR000000 |        | SA     | SA    | SA    |         |



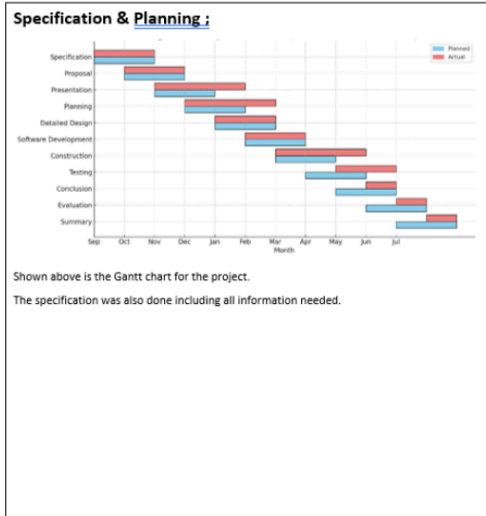
Whole program can be found in project appendix.

|                      |                    |
|----------------------|--------------------|
| Student signature    | <i>S. Phillips</i> |
| Supervisor Signature |                    |
| Lecturer Signature   | <i>Ad</i>          |

Figure 18 – Log sheet 2

## Log Sheet

|                   |    |
|-------------------|----|
| Log No            | 3  |
| No hrs            | 7  |
| Running total hrs | 42 |



|                      |                    |
|----------------------|--------------------|
| Student signature    | <i>S. Phillips</i> |
| Supervisor Signature |                    |
| Lecturer Signature   | <i>AL</i>          |

Figure 19 - Log sheet 3

## Log Sheet

|                      |    |
|----------------------|----|
| Log No               | 4  |
| No hrs               | 3  |
| Running total<br>hrs | 45 |

### Solutions Considered :

Arduino based, Deemed not safe for NHS use due to maintenance level and robustness



Same issue for Raspberry Pi with Python Interface when considered.

|                      |                    |
|----------------------|--------------------|
| Student signature    | <i>S. Phillips</i> |
| Supervisor Signature |                    |
| Lecturer Signature   | <i>AL</i>          |

Figure 20 - Log sheet 4

## Log Sheet

|                      |    |
|----------------------|----|
| Log No               | 5  |
| No hrs               | 5  |
| Running total<br>hrs | 50 |

### Final Solution :



The decision was made for the use of a PLC as the final design, the reasons for this selection can be found within the project text. Main reason being low maintenance and robust.

|                      |                    |
|----------------------|--------------------|
| Student signature    | <i>S. Phillips</i> |
| Supervisor Signature |                    |
| Lecturer Signature   | <i>RL</i>          |

Figure 21 - Log Sheet 5

## Log Sheet

|                   |    |
|-------------------|----|
| Log No            | 7  |
| No hrs            | 20 |
| Running total hrs | 77 |

**Testing and Results ;**

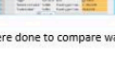
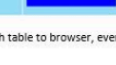
| Test No. | Supervision | Value on Signal | Value on Watch | Watch Table Evidence                                                              | Value on Browser | Evidence of Browser                                                               |
|----------|-------------|-----------------|----------------|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|
| 1        | 20          | 2V              | 13.625         |  | 13.625           |  |
| 2        | 40          | 4V              | 38.623         |  | 38.623           |  |
| 3        | 60          | 6V              | 58.620         |  | 58.620           |  |
| 4        | 80          | 8V              | 73.618         |  | 73.618           |  |
| 5        | 100         | 10V             | 88.616         |  | 88.616           |  |

Table shows multiple test were done to compare watch table to browser, everything worked as expected

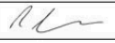
|                      |                                                                                   |
|----------------------|-----------------------------------------------------------------------------------|
| Student signature    |  |
| Supervisor Signature |                                                                                   |
| Lecturer Signature   |  |

Figure 22 - Log sheet 6

Log Sheet

|                      |     |
|----------------------|-----|
| Log No               | 8   |
| No hrs               | 23  |
| Running total<br>hrs | 100 |

**Discussion, Conclusion and Recommendations :**

My discussion, conclusion and recommendation are amalgamated in text, the project worked as should with it passing all tests.

Within the project the recommendations are used to include a point or multiple of how to improve or possibly something that could be done next time within the project.

In the project my recommendations show how this can be completed from an easier and better approach

See contents table to locate this section of my report for further reading

There should be more log entries

|                      |                                                                                   |
|----------------------|-----------------------------------------------------------------------------------|
| Student signature    |  |
| Supervisor Signature |                                                                                   |
| Lecturer Signature   |  |

Figure 23 - Log sheet 7

# 69

/100

PAGE 1

PAGE 2

**Text Comment.** Good table of contents

PAGE 3

**Text Comment.** Good list of figures

**Text Comment.** Good use of tables

PAGE 4

**Text Comment.** Good argument for the project

**Text Comment.** Good point and ref source

**Text Comment.** Good explanation

**Text Comment.** Correct citation

PAGE 5

**Text Comment.** Good points

**Text Comment.** Good explanation

**Text Comment.** Good point made

**Text Comment.** Correct citation

**Text Comment.** There are cet good and relevant points in the research and good ref sources

**Text Comment.** Good outline

PAGE 6

**Text Comment.** Good point

**Text Comment.** Good detailed spec

**Text Comment.** Good cost breakdown

PAGE 7

---

**Text Comment.** Advantages of remote access is identified

**Text Comment.** Good spec with user and environmental needs included

PAGE 8

---

**Text Comment.** Good point

**Text Comment.** Discrepancies have been explained

**Text Comment.** Good Gantt chart

PAGE 9

---

**Text Comment.** Good test plan

PAGE 10

---

**Text Comment.** Supporting image would be useful

**Text Comment.** Good argument for this solution

**Text Comment.** Good features of the Raspberry Pi identified

**Text Comment.** Supporting image would be useful

PAGE 11

---

**Text Comment.** Good evaluations carried out

**Text Comment.** Good features identified

**Text Comment.** Good block diagram

PAGE 12

---

**Text Comment.** Good evaluation

**Text Comment.** Good evaluation table to compare solutions

**Text Comment.** Good argument for chosen solution

PAGE 13

---

**Text Comment.** Good explanation

**Text Comment.** Good evidence and explanation

**Text Comment.** This a good point as he counters were just used to test the data was updating on the browser with the time limits i.e. under 2s

**Text Comment.** Good evidence

**Text Comment.** This is a reasonable assumption

**Text Comment.** Explanations are relevant, however the code in the appendix is not referenced

**Text Comment.** Good summary

**Text Comment.** Third is missing

**Text Comment.** Very good table of results

**Text Comment.** Above

**Text Comment.** Good set of results

**Text Comment.** Explanations could be more detailed here

**Text Comment.** Good conclusion

**Text Comment.** Good relevant recommendations

**Text Comment.** Good number of ref sources

**Text Comment.** Good evidence

**Text Comment.** Good evidence

**Text Comment.** Good evidence

**Text Comment.** This is the main Javascript file

**Text Comment.** Tag ID for javascript

**Text Comment.** Img refresh condition for under temp condition (boolean)

**Text Comment.** There should be more log entries

GRADING FORM: CSG-RUBIC

SION PHILLIPS

0

#### RESEARCH-INFORMED LITERATURE



Good relevant research with good number of sources used. Good research of solutions. Solutions should have ref source for each. However the research did include evaluations.

13/20

#### KNOWLEDGE AND UNDERSTANDING



Specification is very detailed and includes good realistic requirements. 7/10  
Solutions considered have good relevant

14/20

arguments for alternatives for the system. Good evaluations and argument for chosen solution. There should be ref sources included.  
7/10

## ANALYSIS



Table of results is very good with evidence and explanations. Explanations could be more detailed and include the web data part. 7.5/10  
Good conclusion and good relevant recommendations 7.5/10

**15/20**

## PRACTICAL APPLICATION AND DEP.



Good Gantt chart plan with comparison timeline with explanation of discrepancies. A good test plan is also included. 4/5

Solutions considered have good relevant arguments for practical alternatives for the system. Good evaluations and argument for chosen solution. There should be ref sources included.  
7/10

Implementation includes good explanations of the PLC part of the program in general, including the timers that were needed for testing. However, the JavaScript code is not referenced from the appendix for evidence. 5/10

**16/25**

## SKILLS FOR PROFESSIONAL PRAC.



A good structured report with good content quality.

**11/15**