

Project Proposal Report

by Damian Walczak

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University of Wales
Trinity Saint David

**CUSTOM CONTROLLER WITH RS232
COMMUNICATION FOR AN INDUSTRIAL OVEN
TESTING BENCH**

By

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Supervisor: Jenifer Prince Deveraj

Project submitted as part of the requirements for
the award of

BEng (Hons) Electrical and Electronics Engineering

October 2025

Damian Walczak (2015478)

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1. Introduction

PLCs, which are integrated into commercial test rigs, have always been a major component of such testing infrastructure[1]. PLC-based systems have a number of disadvantages despite their shown robustness[2]. They frequently limit scalability and adaptation to the particular requirements of oven specific testing due to their high upfront cost, reliance on vendor specific software, and complex maintenance[3]. For businesses that need flexibility, cost effectiveness, and functionality that is specifically adapted to their needs, relying on general purpose industrial solutions leads to wasteful spending.

By challenging the dependence on PLC-only solutions and suggesting the creation of a unique controller intended especially for oven testing applications, this study aims to overcome these constraints. Crucially, this method offers a number of clear benefits, including a substantial cost reduction, hardware and software customisation, the addition of oven specific features like direct MCB feedback and thermocouple interfacing, and the ability to expand in response to changing needs.

Up to nine outputs will be supported by the suggested system architecture with real-time MCB status tracking, emergency stop functionality, and sensor integration. Feedback will be provided via voltage sensors, current transformers, and a Type-K thermocouple. Through monitoring, system is able to identify overloads or overheating and immediately switch to a safe shutdown mode.

The controller will use RS232, which is widely used[9], to communicate and control with a PC. Operators will be able to watch and control oven testing in real time thanks to the PC program. An DC-DC converter stage will regulate the 24 V supply power to 5 V and 3.3 V for the controller's circuitry.

Architecture and functional goals will be validated by the successful design, construction, and testing of the Stage 1 controller. In terms of flexibility and cost-effectiveness, this stage shows that a microcontroller-based solution may successfully duplicate and outperform PLC.

Stage 1 will highlight a number of areas that needs work. In particular, signal noise in the analogue inputs needed to be reduced, power circuit design was not ideal for manual soldering. During testing, connection issues were also found. These results serve as the basis for the Stage 2 controller, which will include RC filters to lower electrical noise, an enhanced PCB layout, and a reworked power circuit design for simpler soldering.

The goal is to provide an oven specific testing solution that is modular, safe, and economical. Offers alternative to PLC-based systems by combining affordability and expandability, which makes it a desirable small-to-medium businesses.

2. Aim and Objectives

2.1 Aim:

Designing, building and testing a custom embedded controller for an industrial oven testing station is the aim of this project. The Stage 1 controller, which integrates sensor monitoring, RS232-based PC communication for data exchange, and contactor control that directs load to sockets chosen by the PC, has been successfully finished and tested.

Building on the outcomes of Stage 1, the upcoming Stage 2 controller seeks to provide a better hardware design with improved solderability, decreased electrical noise, and refined PCB tracking while including automatic fault protection and adhering to pertinent UK and US electrical and safety standards.

2.2 Objectives:

2.2.1 Ensure compliance and implement safety mechanisms

By monitoring emergency stop signals, adding watchdog protection, and ensuring adherence to PUWER 1998[10], BS EN 61439[11], IEC 60204-1[12], and IEC 62061/ISO 13849[13].

2.2.2 Design and implement reliable output control

By implementing a reliable output control system for the controller. And use N-channel MOSFET drivers to ensure safe, reliable switching.

In order to provide safe and reliable operation, the power circuitry will be changed in Stage 2 for better DC-DC handling for simpler manual soldering, and decreased noise transmission. Also errors will be fixed.

2.2.3 Integrate and test sensor monitoring and data acquisition

By interfacing with current, voltage, and temperature sensors, applying signal conditioning, and enabling real-time measurement.

In order to reduce electrical noise and improve measurement accuracy and signal reliability, Stage 2 will implement RC filters and optimised PCB layout.

2.2.4 Develop PC communication

To enable real-time transfer of sensor data, system status, and control commands.

2.2.5 Evaluate system expandability/cost-effectiveness

Use a modular architecture to support additional oven channels or future functional upgrades.

Keep total system cost within reasonable budget while ensuring reliability, robustness, and long-term serviceability.

3. Background Research

3.1 PLCs in industrial automation

PLCs have long been the cornerstone of industrial automation, providing durability, modular design, and strong vendor support[1]. They enable reliable operation under demanding conditions through standardized input/output modules, built-in diagnostics, and programming via ladder logic[5]. PLCs continuously monitor input signals from devices such as sensors, execute programmed logic, and control actuators or other equipment based on these inputs[2][3]. Inputs from sensors are processed, outputs drive actuators, motor starters. Industrial protocols allow PLCs to communicate with other PLCs or HMIs. Control logic can be programmed in different ways, offering flexibility in implementation[3][5]

3.2 Limitations of PLCs

In many scenarios, the full functionality of a PLC is not required, leaving much of the system not used. High hardware  software licensing fees, and vendor specific support increase the initial investment. Closed architectures reduce interoperability and can lead to complex maintenance requirements[3]. These limitations have motivated my research into alternative control solutions for industrial test benches.

3.3 Alternatives: PCs and Embedded Controllers

PCs and controllers are emerging as cost-effective, flexible alternatives. PCs offer higher computational power, large-scale data storage, and versatile software development platforms, allowing integration of multiple serial communications and fully integrated HMI solutions[6][7]. However, PCs do not have internal relays or switches to control components such as contactors, which are required for testing station power distribution.

For instance, Ahshan et al. developed a microcontroller-based control system for a small induction-generator wind turbine. The study highlighted that while a PLC could have been used, an embedded solution was more cost-effective, met computational requirements, and avoided unnecessary hardware complexity. While embedded systems are highlighted as cost-effective in specific study[8], most existing research is not addressing safety interlocks and PC-based monitoring.

3.4 Research gap for test benches

PLCs remain the dominant choice in industrial automation[1], their high cost, limited flexibility, and complexity make them less suitable for specialized appliance testing environments[3]. Existing literature shows a lack of modular, low-cost controllers that combine real-time monitoring, PC-based connectivity, safety interlocks, and appliance-specific functionality.

4. Project Desing

The suggested system was designed in Stage 1 as a controller that is integrated into a testing bench. Hardware architecture, software development, safety and compliance protocols, testing procedures, and risk assessment are all covered in the project design. The Stage 2 controller, which will have better hardware design, increased ability to solder, and less electrical noise, will be based on the useful data gathered from the conclusion of Stage 1.

4.1 Hardware Architecture

The PIC18F46J50 is the main part of the controller in Figure 1 Hardware Architecture. It was chosen due to sufficient I/O ports, and UART functionality for RS232 connection[14]. The I/O expander will be used to get around its limited number of I/O pins, communicating via I²C. MOSFETs control the controller's outputs by powering contactors and relays. The input signals consist of three current transformer analogue inputs, three voltage sensor analogue inputs, one Type-K thermocouple input, six auxiliary MCB feedback inputs that have been scaled from 24 V to 3.3 V via voltage dividers, and one emergency stop input that has also been reduced to 3.3 V. The 24 V system input will be stepped down into 5 V and 3.3 V rails for the controller and peripherals using an DC-DC converter.

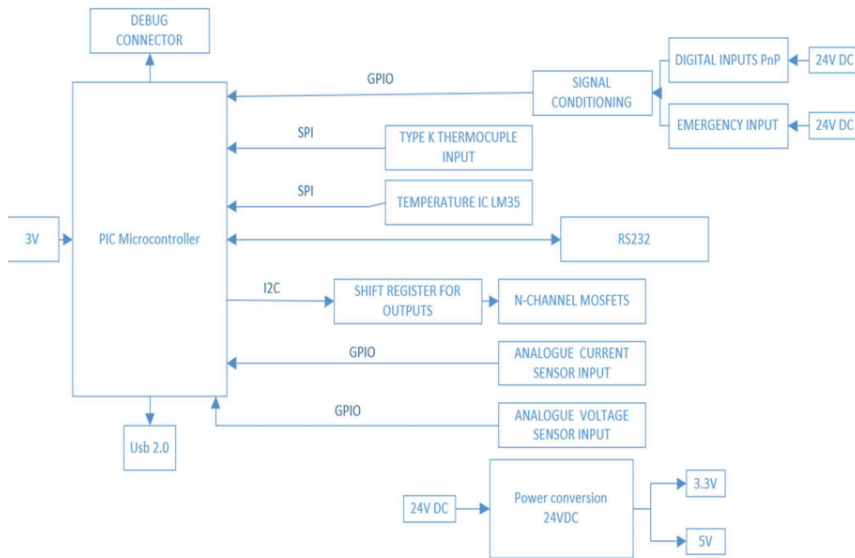


Figure 1 Hardware Architecture

The original power circuit design was found to be unsuitable for manual soldering, which led to difficulties with assembly. This circuit will be modified for Stage 2 in order to simplify hand soldering and increase easy manufacturing. Significant signal noise in analogue inputs was also found, along with a number of routing and connection issues. In order to improve signal stability and reduce disruption, Stage 2 will implement RC filtering and better PCB layout techniques.

4.2 Firmware and Software Design

Using the MPLAB X IDE, firmware will be created in C to handle functions including input monitoring, socket switching logic, communication, and emergency shutdown procedures. Figure 2 Firmware flowchart shows how it should operate.

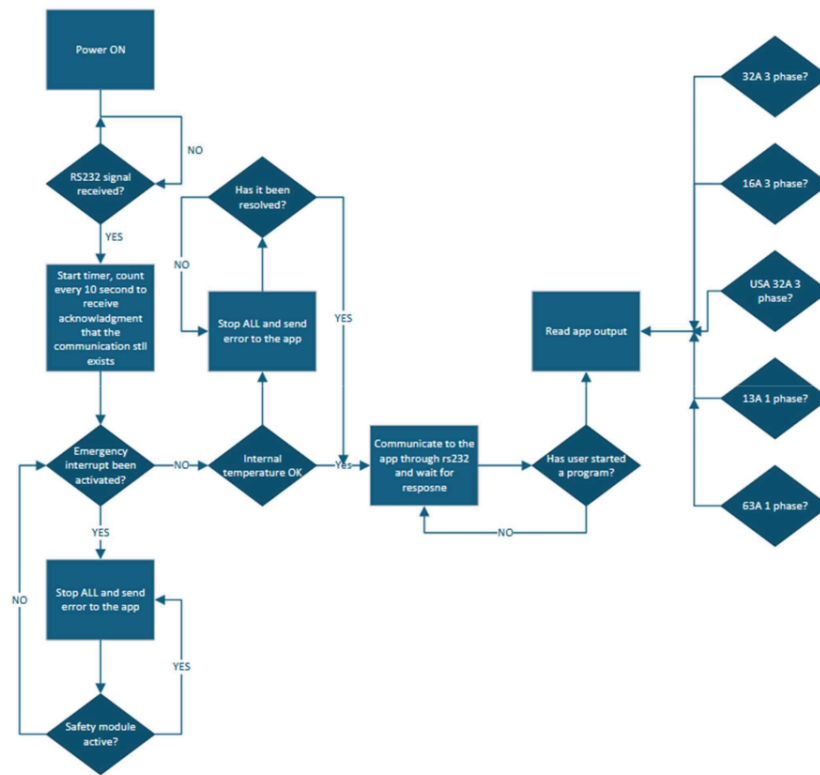


Figure 2 Firmware flowchart

4.3 Safety and Compliance

Compliance with PUWER[10], BS EN 61439[11], and IEC 62061[13] will act as the foundation for safety design, guaranteeing that all systems meet accepted safety requirements. By monitoring on MCBs through their auxiliary terminals, the controller will be able to quickly identify and address any issues. The emergency stop feature will instantly stop controller functioning and put the system in a safe state, going beyond software-based shutdowns.

4.4 Testing Methodology and Risk Management

Socket and contactor switching will be verified by bench testing, and reference meters will be used to calibrate sensors for precise readings. MCB tripping and emergency stop activations will be simulated in safety tests, and the dependability of RS232 communication will be evaluated under load. A watchdog and repeated testing will be used to control firmware failures, thermal hazards will be minimised by thermocouple monitoring, and electrical hazards.

4.5 Ethical Implications

Operators of testing station are protected from electrical risks by internal fuse and emergency stop mechanisms that will shut down whole system when needed. Accurate measurements, sensor calibration, dependable firmware, and strong RS232 connection are all necessary to guarantee data integrity. Clear warnings, documentation, and adherence to standards all help to promote responsible use.

4.6 Environmental and Societal Impact

Industrial ICs with low power consumption and optimised switching, such as MOSFETs and DC-DC converters, are used in the system to save energy and reduce components necessary. Electronic waste can be reduced by choosing durable parts and ICs with built in features. In terms of society, the controller improves oven safety by avoiding accidents and offers accurate testing data that supports safer industrial products with better output.

4.7 Data Analysis and Result Evaluation

Digital inputs, RS232 communication logs, and analogue measurements (temperature, voltage, and current) are all part of the data collection. The relationship between the controller and PC will be evaluated using analysis.

By comparing outcomes with those from calibrated reference devices, the accuracy of the thermocouple will be confirmed. Sensor outputs will be summarised through data analysis. The evaluation also includes performing repeated reliability tests, confirming measured values against expected ranges, and assessing RS232 performance under load.

5. Planning

Table 1 BOM shows all resources used in the project. With the commercial discount, the cost is £60.48. For comparison, the cheapest PLCs on the market are typically priced between £300-£500[15], representing a saving of approximately 80%.

Table 1 BOM

Item No.	Component	ID	Quantity	Total Cost(GBP)	Part Number	Brand
1	PIC18F46J50-I/PT	IC1,	1	4.79	PIC18F46J50-I/PT	Microchip
2	SMD Multilayer Ceramic Capacitor	C4,C1,C2,C8,C10,C17,C18	16	0.384	06033G104ZAT2A	KYOCERA AVX
3	SIMPLE SWITCHER® 3.8V to 6V	PS1,PS2	2	6.192	LMR33620CDDA	Texas Instruments
4	SMD Multilayer Ceramic Capacitor	IC2,IC3,IC4	3	0.6444	12063C105KAT2A	KYOCERA AVX
5	SMD Multilayer Ceramic Capacitor	C3,C9,C18,C19,C20,C32	8	3.7056	12103D106KAT2A	KYOCERA AVX
6	Power Inductor (SMD), 1.5 µH, 6.2 A, Shielded,	L2,L3	2	3.6	74438357015	WURTH ELEKTRONIK
7	Multilayer Ceramic Capacitor	C5,C11	2	0.962	CL32A107MQVNNNE	Samsung
8	SMD Chip Resistor, 100 kohm	R1,R3,R12	3	0.0324	RC0603FR-07100KL	YAGEO
9	SMD Chip Resistor, 24.9 kohm	R2,	1	0.0096	RC0603FR-0724K9L	YAGEO
10	Fuseholder, 6.3 A, 250 V, PH1		1	0.2988	CFH02	CAMDENBOSS
11	Common Mode Chokes Dual	FL1	1	0.9108	SRF0905A-100Y	Bourns
12	Multilayer Ceramic Capacitor	C6,C7	2	1.546	GRM32ER7YA106KA12L	Murata Electronics
13	Pin Header, Shrouded, W/1		2	0.52	B04B-XASK-1(LF)(SN)	JST
14	SMD Chip Resistor, 43 kohm	R4	1	0.0072	MCWR06X4302FTL	MULTICOMP PRO
15	SMD Chip Resistor, 470 ohm	R5	1	0.0096	RC0603FR-07470RL	YAGEO
16	EEPROM 16byte 128b 2.5V	IC5	1	0.205	24LC00-I/SN	Microchip
17	RS-232 Interface IC Dual E	IC6	1	1.27	MAX232IDRG4	Texas Instruments
18	Multilayer Ceramic Capacitor	C12,C13,C14,C15,C16	5	1.944	MCMLR50V105MY5V	MULTICOMP
19	D Sub Connector, W/					
19	Board Lock, DB9,	J2	1	2.556	2301843-1	TE CONNECTIVITY
20	Through Hole Resistor, 10	R6,R7,R47,R48,R49,R50	8	0.7488	MF1/4DCTS2R1002D	KOA
21	Temperature Sensor IC, Th	IC7	1	10.08	MAX31855KASA+	ANALOG DEVICES

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22	Wire-To-Board Terminal Block	J3	1	0.942	1825640000	WEIDMULLER
23	SMD Chip Resistor, 240 ohm	R8,R9,R10,R54,R53	5	0.102	ERJ3GEYJ241V	PANASONIC
24	LED, Red, Through Hole, T-1	LED2,LED3	2	0.8952	MP008247	MULTICOMP PRO
25	LED, Green, Through Hole, T-1	LED1,LED4,LED5	3	0.2973	MCL053GD	MULTICOMP PRO
26	Temperature Sensor IC, Ar	IC8	1	2.244	LM35DZ/NOPB	TEXAS INSTRUMENT
27	Through Hole Resistor, 1 k	R11	1	0.1164	MF50 1K	MULTICOMP PRO
28	Pin Header, R/A, Board-to-board	J4	1	0.1056	MC34751	MULTICOMP PRO
29	I/O Expander, 16 bit, I2C, S	IC9	1	1.608	MCP23017-E/SP	MICROCHIP
30	SMD Chip Resistor, 3.3 kohm	R13,R14,R15,R16,R17,R	10	0.12	RC0603FR-073K3L	YAGEO
31	Power Load Distribution Switch	IC10,IC11,IC12,IC13,IC1	10	12.24	NCV8401BDTRKG	ONSEMI
32	Headers & Wire Housings	J5	1	0.442	B10B-XASK-1(LF)(SN)	JST Commercial
33	Headers & Wire Housings	J6	1	0.205	B04B-XASK-1(LF)(SN)	JST Commercial
34	Crystal, 16.384 MHz, Through	Y1	1	0.27	ABL-16.384MHZ-B2	ABRACON
35	Multilayer Ceramic Capacitor	C23,C24	2	0.5328	FG18C0G2A220JNT00	TDK
36	Through Hole Resistor, 21	R23,R26,R29,R32,R35,R	7	1.1424	MRS25000C2102FCT00	VISHAY
37	Through Hole Resistor, 3.3	R24,R27,R30,R33,R36,R	7	0.7476	MF50 3K3	MULTICOMP PRO
38	Through Hole Resistor, 200	R25,R28,R31,R34,R37,R	7	2.1756	MFR4-200KFI	TT ELECTRONICS / W
39	Zener Single Diode, 4.3 V,	ZD1,ZD2,ZD3,ZD4,ZD5,Z	7	0.4956	1N5229B	ONSEMI
40	Headers & Wire Housings	J7	1	0.489	B08B-XASK-1(LF)(SN)	JST Commercial
42	Phone Connectors 3.5mm	J8,J9,J10	3	2.07	SJ2-3574A-SMT-TR	Same Sky
43	Metal Film Resistors - Thru	R44,R45,R46	3	3.87	8-1879672-0	TE Connectivity /
44	Headers & Wire Housings	J11	1	0.221	B06B-XASK-1(LF)(SN)	JST Commercial
45	USB Connector, Micro USB	J12	1	0.7524	47642-0001	MOLEX
46	PCB PRINT	pcb	1	3.058	PCB	JLL
		MOQ TOTAL NO VAT		75.5581	Estimated discount 20%:	60.44648

6. Planning

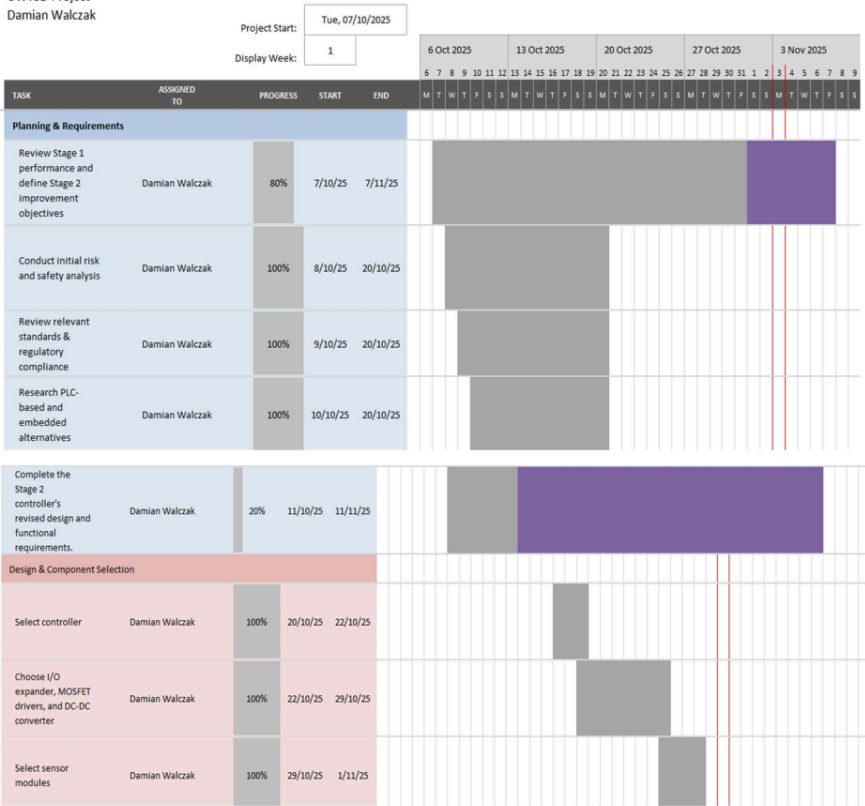
Table 2 Gantt chart table, outlines the finished Stage 1 milestones and the next Stage 2 tasks.

Table 2 Gantt chart

CUSTOM EMBEDDED CONTROLLER WITH RS232 COMMUNICATION FOR AN INDUSTRIAL OVEN TESTIN

UWTSD Project

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Redesign power regulation & distribution circuit	Damian Walczak	50%	1/11/25	20/11/25
Design safety emergency stop circuit	Damian Walczak	100%	1/11/25	12/11/25
Add RC filters to reduce signal noise and improve analogue stability	Damian Walczak	50%	1/11/25	12/11/25
Review and validate new schematic and PCB design	Damian Walczak	80%	1/11/25	25/11/26
Physical Build and Assembly				
Manufacture updated PCB and assemble components and wiring harness	Damian Walczak	0%	25/11/25	1/1/26
Mount sensors and interface boards	Damian Walczak	0%	1/1/26	7/1/26
Verify solderability and perform quality inspection	Damian Walczak	0%	7/1/26	14/1/26
System Integration & Testing				
Power-up and confirm wiring is correct	Damian Walczak	80%	14/1/26	24/2/26
Verify RS232 communication and PC data logging	Damian Walczak	100%	14/1/26	31/3/26
Test sensor input accuracy (current, voltage, temp)	Damian Walczak	100%	14/1/26	31/3/26
Validate firmware: socket switching & fault response	Damian Walczak	100%	14/1/26	31/3/26
Test safety mechanisms such as E-stop or watchdog	Damian Walczak	100%	14/1/26	31/3/26
Documentation				
Finalize schematics, PCB layouts, and firmware documentation	Damian Walczak	80%	31/3/26	30/4/26

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Compile test data, photos, and calibration logs	Damian Walczak	0%	31/3/26	30/4/26
Write final report and cost analysis	Damian Walczak	0%	31/3/26	30/4/26
Compare Stage 1 and Stage 2 performance (accuracy, stability, and ease of assembly)	Damian Walczak	0%	31/3/26	30/4/26
Prepare and deliver final presentation/demo	Damian Walczak	0%	31/3/26	30/4/26

7. Expected Outcome

The completion of Stage 1 has resulted in a fully functional controller prototype. System includes MCB auxiliary input detection, emergency stop functionality, and safety temperature monitoring. With specialised PC software for data recording and control, real-time temperature, voltage, and current monitoring has been effectively implemented.

RS232 communication will demonstrate efficiency in connection between the controller and external systems. The project's profitability will be proven by a thorough cost analysis, and the Stage 1 prototype achieved cost savings of almost 80% when compared to PLC.

All of the knowledge gained from Stage 1 will be included into the next Stage 2 controller to create a better, production-ready design.

Table 3 Stage 2 enhancements shows a list of modifications needed.

Table 3 Stage 2 enhancements

	Enhancements
1	A power circuit needs to be modified to allow for easier production and hand soldering.
2	PCB tracking and grounding needs updating to remove previously found routing problems.
3	To greatly lower electrical noise and increase sensor accuracy, RC filtering and enhanced signal conditioning are needed.
4	Updated firmware for better data collecting, enhanced fault handling, and increased stability needs to be implemented.

In the end, the project will show that for industrial oven testing applications, a microcontroller-based controller can offer a reliable, adaptable, and reasonably priced substitute for PLC systems that provide similar or better performance in areas where customisation, scalability, and affordability are crucial priorities.

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9. Appendix

DECLARATION

I, Damian Walczak declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

Date : 16/10/2025

Project Proposal Report

GRADEMARK REPORT

FINAL GRADE

73/100

GENERAL COMMENTS

Project Proposal – ACCA6020 Independent Project

Student: Damian Walczak

Intro / Aims & Objectives : 15/20

The aim and objectives are clearly presented, and the 1 to Stage 2 is well explained, but the section would benefit from a clearer problem statement and stronger justification linking Stage 1 to the planned improvements.

Clear aims, but needs a clearer problem statement and justification.

Background to the Project / Literature Review : 14/20

A clear and technically sound section with a well-defined real-world example is effectively used to show the benefits of embedded systems over PLCs. The section could be improved by explaining how the limitations affect real-world performance.

Clear, but needs clarity on real-time monitoring.

Project Design : 22/30

Demonstrates strong technical understanding, with clear explanation of the hardware architecture, firmware design, safety and testing methodology. The section is well structured, and the explanation is effective. The following should be added for detail.

1. More detail is needed on how durable parts and components will specifically contribute to reducing electronic waste.

The section explains what data will be analysed but not how it will be collected. It would help to briefly clarify how measurements will be taken, what logging methods are used, and whether any other data is required.

Technically well-explained and well-structured.

Resources / Planning : 12/15

The project is well-planned and organized, as evidenced by the clear time scales, costs, tasks, and durations provided. The plan is clear and well-structured. Ethics form submission is included.

Well-organized plan with clear structure.

Document Presentation: 10/15

The document is clearly structured and easy to follow sections and consistent formatting. Presentation can ensuring uniform spacing, applying justified alignment evenly, and adding more visual elements such as tab support key explanations. There are a few spelling errors corrected. The limitations section would be more effective if the aims as part of the problem statement to improve. Additionally, the ethical considerations would be better as a separate chapter rather than within the Project Design.

Well structured, but needs better formatting, clarity, and consistency.

TOTAL: 73/100

PAGE 1

PAGE 2

PAGE 3

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PAGE 5



Comment 1

Limitations are well explained.

PAGE 6



Comment 2

??



Comment 3

spelling



Comment 4

Well Said.

PAGE 7



Comment 5

could be moved to the next chapter.

PAGE 8



Comment 6

Good Capture.



Comment 7

More details on this is required.



Comment 8

Any data logging is used?

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