RMIT UNIVERSITY

SCHOOL OF ENGINEERING

EEET2096 – EMBEDDED SYSTEM DESIGN AND IMPLEMENTATION

LABORATORY PROJECT

HOME MANAGEMENT SYSTEM

1 AIMS

(i) To design, simulate, implement and test a series of external peripheral interfaces using Keil uVision and an STM32F439 microcontroller.

(ii) To develop an understanding of the design workflow when writing code (firmware) for an ARM-based microcontroller using an Integrated Development Environment (IDE) such as Keil uVision.

(iii) To use the C programming language to develop comprehensive firmware that controls integrated peripherals such as ADC, Timers, GPIO and the UART.

(iv) To use the STM32F439 datasheets to determine and interpret essential characteristics of the microcontroller.

(v) To develop a large-scale C project that will require numerous sub-modules that are required to work together to achieve a common complex task.

2 INTRODUCTION

In this project you will use Keil uVision to develop a complex project that builds on the knowledge gained from previous laboratory assessments. In developing the project, you will work with one additional student (maximum group size of two students) in the same laboratory session (whether face-to-face or virtual) and demonstrate your achievements to the Laboratory Demonstrator at the end of the semester. The application that your group will develop is to be written in C and deployed to a physical STM32F439. For students completing the laboratory component of the course online there will be more strict requirements placed on the simulation and analysis of the problem, however the code will still be deployed to the physical board at a remote location.

The assessment for the project consists of two components – a report and a demonstration (equally weighted at 15% each of the overall course grade (30% total). The project runs over three weeks (weeks 9, 10, 11) and the final demonstration will occur during your laboratory session time in Week 12. The report (in PDF format) and corresponding code is to be submitted to Canvas by Friday, Week 13 at 11:59pm. Note that a late penalty of 10 marks per 24-hour period (inclusive of weekends) will apply for all components that are to be submitted to Canvas.

All work must be original, and plagiarism will be taken very seriously. You must develop all the code between the group and hence reference code is not permitted (apart from the STM32F439_Template.zip file available on Canvas).

The project should follow a traditional design cycle where the system is developed 'on paper' before proceeding to the actual firmware implementation. Important aspects of the code should be simulated and the laboratory time used to deploy the actual developed code to the hardware. The assessment will have a strong focus on verification of the simulation and how the firmware was developed.

In this project, you are required to develop a 'Home Management System (HMS)' using the RMIT STM32F439 Development platform. The aim of the Home Management System is to control a set of virtual sensors and corresponding outputs (simulated fan / heater and light control). The STM32F439 is to be used as a central controller with a range of the internal peripherals used to emulate the sensors. The HMS block diagram is as shown as in Figure 1.

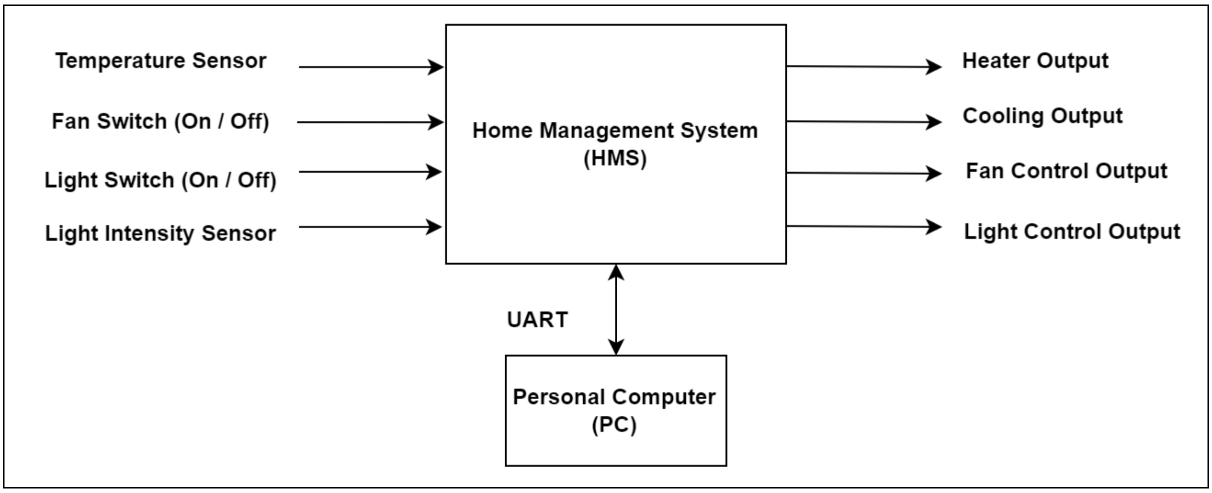

Figure 1 - Home Management System (HMS) - Block Diagram

The system comprises of a temperature sensor (analogue input), a fan and light switch, a heater and cooling output as well as a light intensity sensor (threshold detection). The required I/O mapping (based on the RMIT Development Hardware) can be found in Table 1:

HMS Function	Port / Pin	I/O Type	Development Board Function
Temperature Sensor	PF10	Analogue Input	Potentiometer
Fan Switch	PA3	Digital Input	Up Switch (SW1)
Light Intensity Sensor	PA8	Digital Input	Down Switch (SW2)
Light Switch	PA9	Digital Input	Left Switch (SW3)
Heater Output	PF8	Digital Output	LED 7
Cooling Output	PB8	Digital Output	LED 6
Fan Control Output	PA10	Digital Output	LED 3
Light Control Output	PB0	Digital Output	LED 4
UART3 Receive	PB11	I/O Alternate Function	N/A
UART3 Transmit	PB10	I/O Alternate Function	N/A

Table 1 - Home Management System - I/O Mapping

To control the system, either the buttons indicated in Table 1 or the UART can be used. The UART should be configured to operate at 57,600bps, 8 data-bits, No Parity and 1 Stop Bit (57600, 8, N, 1) and for simplicity should use UART3 which already provides a USB to UART conversion IC (FT232RL). To simplify the design process, the communication protocol (in terms of the packet structure) for transmission of data from the HMS to a PC can be found in Table 2. A terminal emulator (such as TeraTerm) can be used to transmit and receive data to / from the development hardware.

The temperature sensor is emulated by the analogue input, with an ADC value of 0 equating to a temperature of 8°C and 4095 (full-scale) equalling 45°C. Assuming a linear relationship between the ADC value and simulated temperature, an expression will need to be derived to determine the value to be displayed on the terminal window.

A header byte (0x21 – ASCII !) is used to provide a marker (or synchronisation) for the PC to know that the packet coming in is from the HMS. The temperature value (with one decimal point) as should be transmitted next. A total of 4 ASCII characters should be used to indicate the simulated temperature (ie. 22.8 should be printed to the console to represent 22.8°C).

The fields ‘a’,‘b’,’c’ and ‘d’ are used to indicate that status of the light (Bit ‘a’), fan (Bit ‘b’), heater (Bit ‘c’) and cooling (Bit ‘d’) outputs. A logic 1 indicates that the particular device is on, whereas a logic 0 indicates that it is off. The data should be transmitted back to the PC at 1Hz (or once per second). Hint: Use a timer with a 1Hz timeout to trigger the update to the PC.

<table>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>0</td><td>0</td><td>1</td><td>1</td><td>a</td><td>b</td><td>c</td><td>d</td></tr>
<tr><td colspan="8">First byte is a header - 0x21</td><td colspan="8">Temperature Value (4-ASCII values)</td><td colspan="8">a – Light Status (On / Off) - Logic 0 or 1.
b – Fan Status (On / Off) - Logic 0 or 1.
c – Heater Output (On / Off) – Logic 0 or 1.
d – Cooling Output (On / Off) – Logic 0 or 1.</td></tr>
</table>

Table 2 - HMS to PC Communication Protocol

In terms of sending data from the PC back to the HMS a simplified protocol is to be used as illustrated in Table 3. The header byte is 0x21 (ASCII ‘!’) followed by a second byte which is used to turn on / off both the light, fan heating and cooling control lines as described in Section 3. Note that the heating and cooling outputs are mutually exclusive.

<table>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>a</td><td>b</td><td>c</td><td>d</td></tr>
<tr><td colspan="8">First byte is a header - 0x21</td><td colspan="8">a - Light Control (On / Off) - Logic 0 or 1.
b - Fan Control (On / Off) - Logic 0 or 1.
c – Heater Output (On / Off) – Logic 0 or 1.
d – Cooling Output (On / Off) – Logic 0 or 1.</td></tr>
</table>

Table 3 - PC to HMS Communication Protocol

The Light and Fan switches operate as toggle buttons. For example, assume that the current status of a switch is ‘on’. If a press of the switch is detected, then the device will turn ‘off’. If another press is detected the device will turn back ‘on’. Figure 2 illustrates a simplified electrical interpretation of a single switch being pressed. It is assumed that the switch is high (logic 1) when not pressed and low (logic 0) when pressed.

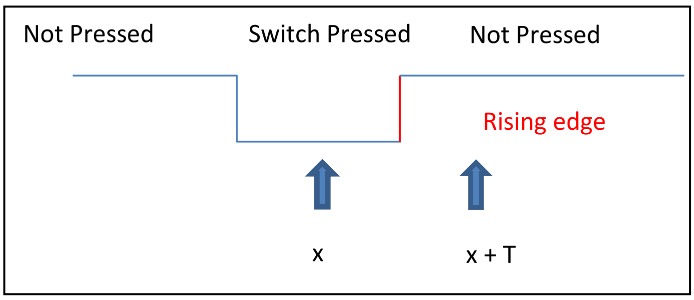

Figure 2 – Switch Edge Detection

In Section 3, a button should only be registered after it has released (rising edge detection). One way that this can be achieved is by detecting the first edge transition at 'x' (falling-edge) and then sampling the I/O pin for at least 500ms. If the button is released prior to 500ms (T < 500ms), then the system should detect that the minimum timeout has not been achieved. Provided that the button is held down for at least 500ms second (x + T), and the rising edge detected, then a button press can be registered and passed through for processing.

To detect the rising edge, the program has to keep the previous input pin reading denoted **switchValue(x)**. If the previous reading switchValue(x) is low and the current reading **switchValue** (x + T) is 1, then a button press is detected at which point a flag indicating a toggle should be set provided a one second timeout has occurred.

3 PROBLEM DESCRITPION

This project requires students to build a Home Management System (HMS). The specifications of the system are as follows:

a) Once per second the system parameters are to be sent out via the UART (to the PC) for monitoring. The default set of parameters are:
   - Current Temperature Value (4-ASCII values, truncated to a single decimal point).
   - Light Control Output Status (On / Off).
   - Fan Control Output Status (On / Off).
   - Heater Control Output Status (On / Off).
   - Cooling Control Output Status (On / Off).

b) The switches to control the light (Light Switch) and fan (Fan Switch) are to operate in a 'toggle' mode. For example, pressing the switch once will turn on / off the function (latched output). The switch must be pressed for a minimum of 500ms to be successfully registered.

c) The target temperature to be maintained is 23°C. If the temperature is below 22°C then the heater and fan outputs should be turned on. If the temperature is above 24°C, the cooling and fan outputs should be turned on. The heater and cooling outputs are mutually exclusive (only one can be on at a given point in time). The user can press the fan switch to automatically switch the fan off for a period of 15 seconds (the system will still be in heater / cooling mode).

d) The light intensity sensor is used to detect whether a preset illumination already exists. If SW2 is pressed then it indicates that the room is fully lit and pressing the Light Switch will **not** turn on the light output. If SW2 is not pressed, then the lights can activate by pressing the Light Switch as described in 3b).

e) Via the UART, the light can be turned on / off irrespective of the light intensity value. If the UART light turn off command and light switch press occur within one second of each other, then the UART command will take priority.

f) Equally, via the UART the heating / cooling can be turned on or off however it will consider the current temperature. If the temperature is between 18°C and 26°C, then the command to turn on / off the heating / cooling / fan will be accepted for 15 seconds and then the automatic control (as indicated in Section 3c) will resume. If the temperature range is above 26°C or below 18°C the UART command to control the heater / cooling and fan will be ignored. Should the temperature value change during the 15 second UART control, the automatic control should not resume.

4 REPORTING REQUIREMENTS

The assessment schedule and a description of the required documents appear below. Please ensure that you thoroughly read through the assessment rubrics to understand the required outcomes of the project.

Week 12 – Project Technical Demonstration

You will be required to demonstrate their complete project to the Laboratory Demonstrator during their allocated laboratory slot in Week 12. Each student group will have approximately seven (7) minutes to describe and demonstrate their technical achievements. A further three (3) minutes will be made available for questions. Additional material, such as diagrams and images can be used to support the discussion. The demonstration component accounts for 15% of the total available course grade. Note that the demonstration is informal and will generally involve viewing the project outcomes around one of the laboratory computers. Students are requested to ensure that their project is functional prior to the assessment time. No time compensation will be given if the project is not ready to view at the schedule time.

Week 13 – Project Technical Report

Students are required to individually submit a group final project technical report (maximum of ten (10) pages in body of report) describing the work undertaken during the project. The report should be written in such a way that it can be read and understood by another Engineer with a background in STM32F439 design and development. Note that the same report is to be submitted by both group members.

The report (and background material relating to the development of the project including schematics, PCB layouts and **source code**) must be submitted to the subject Canvas website by Friday, Week 13 at 11:59pm. The report is to be in PDF format only and the entire Keil uVision project submitted in .zip format.

A late penalty of 10 marks per day 24-hour period (including weekends) will apply if the required content is note received by the due date / time. The report accounts for a further 15% of the available course grade.

As a general guideline the project report should include, but not be limited to, the following sections:

- Title page: include the project title, the date, student ID and name(s) and the revision number.
- Executive summary: state the main achievements of the project. This is a summary of key findings, achievements, and measurements. It is not an introduction. The words limit is 150.
- Table of contents: section titles and page numbers for your report.
- Introduction: provide an overview and define the scope of the project.
- Essential background information: a brief indication of what references and external information were sought and used. The background information should be limited to technical information that is relevant to explain the concepts and problems addressed in the project.
- Technical work and Results (You may choose own section titles here): this part may contain a description of the process used to develop the deliverables and a complete description of what has been created. Students can elaborate on their contribution to the project and compare obtained results with those in literature or other known solutions. A comparison should be undertaken against the original deliverables of the project and what has been delivered. If discrepancies exist then the reasons should be elaborated (even incorrect or unexpected results and still worth discussing). This

section should form the bulk of the report. Technical content may include diagrams, relevant truth-tables and block diagrams explaining the ‘C’ code used in realising the solution. Simulation results can also be included in the report to explain / demonstrate project outcomes.

- Discussion and Conclusion: Students should provide a discussion of the results, clearly stating their achievements, lessons learnt and possible future works.
- Appendices: These must also be properly titled and should contain details which are of secondary importance in understanding the report. Examples include program listings, schematics, detailed specifications of important components, and derivation of not so well known mathematical functions or theorems used in the report. Note that the full code solution does not need to appear in the appendices as it is to be submitted electronically.

5 RECOMMENDED REFERENCES

[1] ST Microelectronics, “RM0090 – Reference Manual”, ST Microelectronics, June 2018, Available Online.

[2] ST Microelectronics, “STM32F437xx, STM32F439xx Datasheet”, ST Microelectronics, June 2018, Available Online

EEET2096 – Laboratory Group Project Demonstration (Week 12)

The Project Technical Demonstration accounts for a total of 15% of the course grade for EEET2096. The demonstration is to be marked out of 100 and then will be converted to an appropriate percentage. When marking the demonstration factors such as technical complexity, clarity of presentation, technical content, demonstrated technical skills and analysis of results should be considered.

	0 – 49 (NN)	50 – 59 (PA)	60 – 69 (CR)	70 – 79 (DI)	80 – 100 (HD)	Score (%)
Presentation - Style (10%)	Relies entirely on reading from notes and / or did not look at assessor. Unable to convey to assessor the nature of the project. Unable to answer questions posed by the assessor. Vague contribution to the discussion / relies on other group member(s).	Relies heavily on notes and / or makes little eye contact with assessor. Struggles to clearly explain the nature of the project to assessor. Struggles to answer questions posed by the assessor. Limited contribution to the discussion / relies on other group member(s).	Refers to notes at times but makes reasonable eye-contact with assessor. Nature of the project is conveyed reasonably well and is generally understandable. Responds to most questions but answers some incorrectly / lack of confidence. Discussion is vague and relies on prompts from group member(s).	Has little to no reliance on notes and makes good eye contact with audience. Shows an understanding of the nature of the project and conveys this well to assessor. Can answer all questions with reasonable confidence. Time is evenly split between group member(s) however limited indication on the individual contributions.	No reliance on notes and presents in an effective and innovative style. Clearly explains the nature of the project and generates enthusiasm for the topic with the assessor. Answers questions confidently and correctly. Time equally divided between both group member(s) with clear evidence of individual contributions.	
Presentation / Demonstration - Technical Content (90%)	Minimal technical content presented. Inappropriate or insufficient details to support results, e.g. opinions stated instead of facts. No analysis of results or comparison against original aims. System has not been simulated to determine whether it is functionally operational. Investigation method not discussed or described poorly. Has not been able to solve technical problems at an appropriate level.	Understands some of the topic but struggles to make connections with the results. Investigation method discussed but is flawed. No alternative methods described. The simulations developed do not demonstrate sufficient technical complexity or are lacking in analysis. Poor comparisons drawn between original specifications and the presented outcomes. Limited ability to solve technical problems or incorrect / inappropriate	Superficial evaluation of results presented. Investigation method is generally sound, mention has been made to alternative methods but justifications may not have been given for why one method was used over another. Functional simulations have been performed to verify the sub-module design, however may not include all possible states / or contain minor errors or invalid assumptions. Comparison between expected outcomes and actual results lacks	Sound analysis of results presented. Investigation method used has been described and justified. Some alternative methods have been considered and described. Functional simulations are verified against the system output. Advanced diagnostic tools such as oscilloscopes have been utilised to determine (and rectify) errors where appropriate. Comparison of actual results versus original specifications is sound. Technical detail correct and informative.	In-depth analysis of results presented. Investigation method(s) well demonstrated and justified. Alternative methods have been thoroughly researched. Functional simulations are complete and verify complete system functionality. Demonstrated ability to resolve errors and implement appropriate solutions. Where appropriate output has been verified with tools such as oscilloscopes or logic analysis.	

	Technical skill and complexity of solution are inadequate. Presented outcomes are not satisfactory. System is not in working condition and / or system is not available for assessor to see.	methods applied. Technical skill and complexity of the solution are marginal. Students have performed little technical work over the project. Minor parts of the system may be working but largely it does not work to specifications.	technical detail. Technical problems have been addressed and solution is adequate although cumbersome. Fair progress has been demonstrated by the student. System achieves most of its specifications but may stop working intermittently or have an inconsistent output. System may need to be constantly reset to negate errors in the design.	Has demonstrated an ability to solve technical problems using standard accepted techniques. Good progress has been demonstrated by the student. A system has been developed that works to required specifications. System was well demonstrated to show its effectiveness and reliability.	Excellent comparison between actual and expected results. Clearly demonstrated ability to solve technical problems using advanced methods. Exceptional progress has been demonstrated by the student. An innovative system / solution has been developed that works exactly as specifications require. Extra functionality may have also been included.	

EEET2096 – Laboratory Group Project Technical Report (Week 13)

The Project Technical Report accounts for a total of 15% of the course grade for EEET2096. The report is to be marked out of 100 and then will be converted to an appropriate percentage. When marking the report factors such as technical complexity, clarity of discussion, appropriate choice of detail, demonstrated technical skills and analysis of results will be considered. Important concepts must be clearly explained and sources quoted appropriately.

	0 – 49 (NN)	50 – 59 (PA)	60 – 69 (CR)	70 – 79 (DI)	80 – 100 (HD)	Score (%)
Reference Reading and Theoretical Backing (10%)	Report contains limited relevant background information and restates simple facts. Significant technical errors are present in the report illustrating gaps in knowledge. Irrelevant technical references are included or no references at all.	Basic background theory presented covering the topic on a superficial level and missing key technical details. Technical errors exist in the document which raises concerns on the presented outcome.	Background theory (device operation) is sound and covers many of the relevant areas of the project. Report is technically sound, however may be lacking in appropriate technical detail.	Background theory (device operation) shows good research abilities and covers most of the relevant areas of the project. A solid technical discussion has been held demonstrating an in-depth understanding of the topic.	Background theory (device operation) demonstrates exceptional research skills covering all relevant topics for the project. A comprehensive summary of considered techniques have been presented and fully discussed which have led the successful completion of the stage of the project.	
Logical and Convincing Presentation / Layout Diagrams and Photographs (10%)	Report contains a large number of spelling and grammatical errors. Figures are incorrect / difficult to interpret and no discussion has been held on the material presented.	Some spelling and grammatical errors present. Supporting figures are present however may not be 100% clear or limited discussion has been held on their meaning.	Spelling and grammar was of an acceptable level. Graphs and figures were clear but may have had unclear titles/captions. Figures have been linked back to the main text.	Spelling and grammar mostly correct. Graphs and figures are mostly clear and labelled. A discussion has been held on the figure and how it relates to the project.	Exceptional use of language. No spelling / grammatical errors. All figures are clear and well labelled. A thorough discussion has been held on their meaning and purpose.	
Technical Merit (80%)	Functional block diagram of system is not present / does not describe the relevant I/O. Design simulation is inadequate or not discussed. Deployed code was non-functional / results incorrect. Design / schematic / relevant portions of code	Functional block diagram of system is present however does not describe the relevant I/O or is lacking in detail. Design simulation has been performed, however no discussion has been held. Partially functional code with poor verification and justification.	Functional block diagram of system is sufficient and describes the basic I/O requirements. Design simulation is suitable and important features noted. Simulation output was operational however results were not explained. Code is functional however limited	Functional block diagram and of system is well constructed. Simulation output demonstrates a fully operational design and important features discussed. Code is functional and described in detail. Design / schematic relevant code presented	A comprehensive functional block diagram has been developed listing essential details. Simulation is exceptional and comparisons have been clearly drawn between theoretical and experimental results. Simulated design was fully operational and a complete comparison	

	not presented. Investigation method not discussed or described poorly. No analysis performed on results obtained. Unable to make links to theoretical concepts and / or irrelevant facts were used to try to explain results. The techniques employed do not demonstrate a sound technical understanding of the topic. Results have not been presented in a coherent fashion with limited discussion. Conclusions are not present or are technically flawed. Significant issues exist with the outcome of the project.	Design / schematic relevant code presented. Simulation was partially functional with questionable results presented. Superficial analysis of results presented. Results have not been linked back to existing theory presented in the technical literature review section. Can make basic links to theoretical concepts but lacks in-depth understanding. Significant gaps exist in the analysis of the results. Inappropriate conclusions have been drawn from the presented results. Outcomes are marginal and rely on existing work rather than demonstrating the students' ability. The techniques demonstrated highlight sufficient gaps in the students' knowledge. Conclusions are lacking detail.	discussion on design verification / justification. Design / schematic / relevant code presented. A reasonable analysis has been made of results, but may be lacking some depth. Can make reasonable links to theoretical concepts to explain results. Investigation method undertaken is adequate but student may not have considered more effective alternatives. Slight gaps exist in the students' knowledge. Conclusions are sufficiently detailed however no technical justification has been presented. Outcomes are acceptable however a more thorough analysis should have been performed to explain unexpected results.	and appropriately justified. A good analysis of results presented. Investigation method undertaken was sound and appropriate for the project and student demonstrates they have a firm grasp of the theoretical aspects of the project. Outcomes are well documented and have been thoroughly explained. Unexpected results have been considered and an appropriate hypothesis formed. Conclusions and recommendations are justified and a solid technical discussion is present.	drawn between the theoretical and experimental results. Developed code clearly meets all prescribed targets and verified with supporting documentation. Design / schematic / relevant code presented and fully explained. In-depth analysis of results presented. Advanced investigation method proposed that shows solid understanding of project requirements. Students demonstrate an advanced comprehension of the topic and have successfully completed the project. Conclusions made should be justified and well explained. Outcomes are exceptional.	