University of British Columbia
Electrical and Computer Engineering
ELEC291/ELEC292

Project 1 – Reflow Oven Controller

Introduction

Reflow soldering is the dominant technique used to assemble surface mount devices (SMDs) into printed circuit boards (PCBs). Reflow soldering uses solder paste (a sticky mixture of solder flux and tinny solder pellets) to attach components to solder pads in the PCB. Once all the components are 'glued' in place with solder paste, the PCB is carefully heated up. During this heating process the flux is activated and the solder pellets melt, permanently attaching the components to the PCB. This process is referred as "reflow soldering". One common way of heating up the PCB is by placing it inside a reflow oven. For this project you will design, build, program, and test a Reflow Oven Controller.

Project Requirements

Design, build, program, and test a Reflow Oven Controller using any microcontroller/processor except the AT89LP51RC2 or any other member of the same microcontroller series (AT89LP series from Atmel/Microchip). A couple of boards that use the P89LPC9351 microcontroller (an 8051 compatible microcontroller made by Phillips/NXP) are included in the project 1 kit. Instructions on how to assemble and use these boards are available in the web page for the course. The requirements for the Reflow Oven Controller are:

1. **Programmed in assembly language.** The software of the Reflow Oven Controller must be written in assembly language.
2. **Temperature Measurement.** Your reflow oven controller should be capable of measuring temperatures between 25°C and 240°C. For this purpose you MUST use a K-type thermocouple with cold junction compensation. About 2 meters of K-type thermocouple wire is included in the parts kit for project 1. Please <u>do NOT cut the thermocouple wire</u>; it needs to be long to reach the toaster oven from your circuit.
3. **Toaster Oven and Solid State Relay Box.** The Reflow Oven Controller must operate a standard of-the-shelve 1500W toaster oven using a solid state relay (SSR). Toaster ovens and SSR boxes are installed in MCLD 322 and MCLD 303 for this purpose. The controller must regulate the amount of power delivered by the oven using any method (Pulse Width Modulation (PWM), for example, seems to work well) on the control signal of to the SSR.
4. **User Interface and Feedback.** The Reflow Oven Controller must have the following functionality:
    a. Selectable reflow profile parameters such as soak temperature, soak time, reflow temperature, and reflow time. These or equivalent parameters should be selectable using pushbuttons.
    b. Display of temperature(s), running time, and reflow process current state using an LCD attached to the system.
    c. This year the oven controller has to "talk" as part of the user interface. This task is accomplished by using Pulse Coded Modulation (PCM) together with a Digital to Analog Converter (DAC). Fortunately, the P89LPC9351 includes DACs that can be used for this purpose. Since storing PCM sound requires significantly large amounts

of non-volatile memory, the 25Q32 4 Mbyte SPI flash memory is included in the project 1 kit. Instructions on how to generate, store, and playback PCM files using the P89LPC9351 microcontroller are available in the web page for the course. The oven controller should play back the current oven temperature every 5 seconds or so, and indicate the current state of reflow process in English.

d. Start/Stop pushbutton. A pushbutton will be used to start the reflow process. A switch or pushbutton will be used to stop the reflow process and turn off the toaster oven at any moment of the reflow process. The stop function must be independent of the reset button of the system.
e. Temperature strip chart plot using the serial port of the system and a personal computer. The Reflow Oven Controller must send the current oven temperature, in degrees Celsius, through the serial port of a personal computer at a rate of one reading per second. Software running in the computer will read the information from the serial port and plot the temperature in real time to provide feedback about the reflow process.

5. **EFM8 boards**. Included in the project 1 parts kit for ELEC291/ELEC292 are six EFM8 PCBs and all the components required to assemble them. As part of the work for project 1 you must assemble at least three (3) of these boards by applying solder paste using the stencil included in the kit, place the SMD components using the non-magnetic tweezers and magnifying loupe also included in the kit, and solder the components using the toaster ovens, SSRs, and your Reflow Oven Controller. These boards will be used for labs 4, 5, and 6, as well as the second project of course. If you feel confident enough about your controller you can reflow one of these boards during the project demonstration.
6. **Automatic cycle termination on error**. If the reflow process is started without the thermocouple wire inside the oven, it is possible to reach temperatures high enough to burn (as in catch fire!) any PCB placed inside the oven. As a safety measure, the reflow process must be aborted if the oven doesn't reach at least 50^{o}C in the first 60 seconds of operation.
7. **Temperature validation data**. Use the lab multimeters to validate your controller temperature measurements. The maximum acceptable temperature error of your controller is ±3°C for the range 25°C to 240°C. You must include the procedure and the data in the project report. This data must be available during the project demonstration.

Of course, you can add extra functionality and features which will considered when assigning the project mark.

Due Dates

The project functional demonstration and interview will be carried on the week before the reading week break. The report is due the week after the reading week break.

Project Evaluation

The evaluation of this project consists of a functional demonstration and interview (worth 25% of the final mark) and a written project report (worth 5% of the final mark). In the project demonstration, your design is evaluated using the following criteria:

Mark	**The project:**
9.0-10	Is exceptional, did everything it was supposed to do well plus lots of additional functionality.
8.0-9.0	Did everything required, circuitry / project well designed / some additional functionality.
8.0	Did everything required. The project lacks originality, innovation, or extra functionality.
7.0-8.0	Mostly worked, not entirely, not the greatest design.
6.0-7.0	Didn't really work, ok design but didn't really come together.
5.0-6.0	Didn't work, not very good design.
0.5-5.0	Didn’t work, poor design. (Pile of parts!)
0	No project demonstrated.

The project demonstration evaluation and interview will be carried out by the course instructors and two or more laboratory TAs at the dates given above. This demonstration should not take more than 5 to 10 minutes if everything is working reasonably well.

Team Self Evaluation

Similar to what has been done in previous years and other courses, the team members will determine the final mark distribution. There will be 100 total percentage points available per student. For example, if a group has six students, the total number of percentage points will be 600. The team will assign a portion of these points to each member, and the final individual mark will be computed by multiplying the group mark by this individual percentage. For example:

Project 1 Grade (out of 30%) = 20% (function) + 4% (report) = 24%

Student	**Points**	**Grade**	
Liu Kang	120	28.8%	
Johnny Cage	110	26.4%	
Goro	60	14.4%	Failed!
Raiden	90	21.6%	
Sonya	110	26.4 %	
Scorpion	110	26.4 %	
TOTAL	**600**	**24% (mean)**	

If the team is in disagreement about the individual percentage assignments, the individual percentage assignment will be determined by the course instructor and/or TAs by means of interviews and laboratory book reviews.

Project Report Format

The project report should be written for a reasonably expert reader such as a project manager (an engineer) in a company for whom you might have designed this prototype product. The project report should have sufficient detail that someone skilled in the art could reproduce or improve upon your results. The number of pages for the report should be ≤ 20 (not including the title page and appendices, double spaced, ‘Arial’ or ‘Times New Roman’ font size 12 for text, and ‘Courier New’ font size 8 or 10 for the source code, approximately one inch margin for the top, bottom, left, and right margins) and include the following sections:

1. **Title Page** – It should include the course name and number, instructor name, section, project name, group number, names and student number of the students in the group, the percentage contribution of every member in the group (with each student signature), and the date of submission. If the front page is missing any of this information, 2% will be deducted from the project report mark.

2. **Table of Contents**

3. **Introduction** – Design objective and specifications. Overview of the overall design approach including **system block diagrams for both the hardware and software designs**.

4. **Investigation** – This section must include the following subsections:

   A. **Idea Generation** – Describe how your group generated ideas and working hypotheses.
   B. **Investigation Design** – Describe how you group perform the design investigations involving information and data gathering, analysis, and/or experimentation.
   C. **Data Collection** – Describe how your group used appropriate procedures, tools, and techniques to collect and analyze data.
   D. **Data Synthesis** – Describe how your group synthesized data and information to reach appropriate conclusions.
   E. **Analysis of Results** – Describe how your group appraised the validity of conclusions relative to the degrees of error and limitations of theory and measurement.

5. **Design** – This section must include the following subsections:

   A. **Use of Process** – Describe how your group adapted and applied general design processes, accesses to design systems and components, or processes to solve open-ended complex problems as relevant for this project.

   B. **Need and Constraint Identification** – Describe how your group identified customer, user, and enterprise needs, and applicable constraints.

C. **Problem Specification –** Describe how your group specified additional design requirements based on needs and constraints presented in the point above.

D. **Solution Generation** – Briefly describe potential design solutions suited to meet functional specifications. If possible, include even those that didn't work!

E. **Solution Evaluation** - Perform systematic evaluations of the degree to which several design concept options meet project criteria. Clearly explain why you choose the final design.

F. **Detailed Design** – Explain how you applied appropriate engineering knowledge, judgment, and tools, in creating and analyzing design solutions. This has to be one of biggest parts of the report. In this section you must include the description and evaluation of each block (e.g. "A-stable Circuit", or "Counter Initialization"): Describe the approach taken to design each block. For circuits, include a detailed circuit diagram and describe how it works. For programs, include the source code in the appendices, and refer to it while you describe it.

G. **Solution Assessment** – Describe how you assessed the design performance based on requirements, needs, and constraints. This section must include an **evaluation of the complete system** by mean of tests you carried out including plots of performance, reproducibility numbers, tables, etc. as judged appropriate for this project. Describe how each relevant part of your design was tested and the testing results. Also in this section, the strengths and weaknesses of the design must be pointed out.

6. Live-Long Learning – Identify a specific learning need or knowledge gap. For example, did your learn something new by yourself? You didn't take a course that would have helped with the project? You found that one of the courses you took was particularly useful for the project?

7. Conclusions – Summarize the design and functionality of your project. Summarize also the problems you encounter, and how many hours of work the project took.

8. References – A specific book, paper, datasheet, or website is referred to in the **body** of the report at the point at which you say something about it, by a numerically-ordered, square-bracketed number, the first one being [1]. Then, at the end of the Report in a section called **REFERENCES** located just before the **Appendices** section**,** the same square-bracketed number is followed by the Author List, Article Title, Journal or Book Title, Volume, Number, Pages, ISBN Number, Publisher, Date of Publication. Although the Reference list can be listed alphabetically by author, instead we do not recommend this for an Engineering Report. With an alphabetical listing, the location in the body where any particular reference is discussed is then hard to find, since the references are no longer in order of appearance. Examples of references are [1] and [2] (note that the numbers in the square brackets here refer to the appropriate numbers in the Reference list). The Reference list itself might look like:

REFERENCES
[1] Smith, J, and F. Jones, "Designing an universal logic circuit", Journal of Impossibly Wonderful Electronic Circuits, v.3, n.1, pp. 21-35, March, 1910.
[2] Jones, F and J. Smith, "Why universal logic circuits are impractical" , …

9. Bibliography – Items in a section at the end of a report called **BIBLIOGRAPHY** are NOT referred to in the body of the report. It is a list of appropriate background or additional reading and is located after the **References** section and before the **Appendices** section. The items in the Bibliography are usually ordered by last name of the first author. It is sometimes appropriate to have BOTH a Reference list and a Bibliography list. An example Bibliography looks like:

BIBLIOGRAPHY
• Sedra, A., and K.C. Smith, Microelectronic Circuits, 4th Edition, Oxford University Press, 1998.

8. **Appendices –** Supporting documents such as extensive theoretical analyses, mechanical drawings, and source code. Your source code should be properly documented and indented. Do not append datasheets, compiler manuals, or other already published material to the report.

Project Report Marking Rubric.

Report Content	**Worth**	
Title page (all information present including student names/numbers/section?)	0.2	
Table of contents	0.25	
Introduction	0.3	
Investigation		
Idea Generation	0.2	
Investigation Design	0.2	
Data Collection	0.2	
Data Synthesis	0.2	
Analysis of Results	0.25	
Design		
Use of Process	0.25	
Need and Constraint Identification	0.25	
Problem Specification	0.25	
Solution Generation	0.35	
Solution Evaluation	0.2	
Safety/Professionalism	0.2	
Detailed Design		
Hardware block diagram?	0.5	
Circuit explained?	1.0	
Software block diagram?	0.5	
Software explained?	1.0	
Solution Assessment		
Tests include data/plots?	0.5	
Life Long Learning	0.2	
Conclusions	0.5	
References (present and used correctly?)	0.25	
Bibliography (present and used correctly?)	0.25	
Appendices (if present, used correctly?)	0.25	
Report Format		
Double space?	0.25	
Correct Fonts?	0.25	
Margins?	0.25	
Number of pages? (<20 not including appendices)	0.25	
Clear & clean figures? (Bad scans of poorly hand drawn figures are not acceptable)	0.25	
Page numbers.	0.25	
Clean presentation.	0.25	
Weeks late (-2 points per week)		
GRADE (out of 10)		

Sample report front page

University of British Columbia
Electrical and Computer Engineering
ELEC291/ELEC292 Winter 2017
Instructor: Dr. Jesus Calvino-Fraga
Section 201

Project 1 – Reflow Oven Controller

Group #: B4

Student #	Student Name	%Points	Signature
91234567	Liu Kang	120	
97878474	Johnny Cage	110	
96456637	Goro	60	X
94214331	Raiden	90	
96562002	Sonya	110	
99873737	Scorpion	110	

Date of Submission: February 26, 2018