FINAL REPORT
CLICK SENSOR HUB

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INGRAM SCHOOL OF ENGINEERING

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Revision History			
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1 OVERVIEW

1.1 Executive Summary

Working with our sponsor, Dr. Kemp at NXP, and our faculty advisor, Dr. William Stapleton at Texas State University, we have designed an add-on board for the FRDM-KL46Z (a development platform built on the Arm® Cortex®-M0+ processor). Our board will convert 24 out of the 64 pins available in the KL46Z to 4 MikroBus Standard sockets. These 4 sockets facilitate communication with 600+ Click Sensors. The user simply connects the KL46Z to our board, connects any combination of Clicks into the sockets and is ready to begin developing.

Our team is comprised of 3 members:

- Project Manager: Alfonso de la Morena (Computer Engineering)
- Dylan Dean (Micro – Nano Devices)
- Mohamed Sghari (Micro – Nano Devices)

Despite the project not meeting all its initial goals. It is still considered a success in some respects that it set out to achieve. In summary below:

- The project set out to create a board that allowed a FRDM-KL46Z board to interface with any of 4 different MikroBUS standard sockets and it achieved this goal.
- The project set out to create a board that could power a FRDM-KL46Z board and 4 different MikroBUS devices (at 3.3V or 5V) and it achieved this goal.
- The project set out to create a website to display all code, hardware files and user guides necessary and it achieved this goal.
- The project set out to create functional code for all 10 selected Click sensors to interface simultaneously with the FRDM-KL46Z via our board and it failed this goal.

1.2 Abstract

The Click Sensor Hub team has the goal of creating a PCB that simplifies the process of connecting multiple devices that follow the MikroBUS standard to NXP's FRDM-KL46Z board. Our design accomplishes this by sharing lines across the 5 supported communication channels. For example, the SPI channel can share MOSI, MISO and CLK pins. This means we can condense what would have been 16 (4x4) pins to connect four channels to 7 (3+4) pins.

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4 PROBLEM DESCRIPTION

The Click Sensor Hub project was created with the intention of being a useful tool that students in Dr. Stapleton's Microprocessors class at Texas State University could use for the many labs that course requires. The designed PCB board creates a bridge between the FRDM-KL46Z (the board students are given at the beginning of the semester) and 4 MikroBUS standard sockets. The MikroBUS standard, which is discussed in more detail in the Technical Spec Document, is used to connect what are known as Clicks.

The Clicks are simple devices meant for prototyping and adding sensor capabilities to microprocessors. To communicate, Clicks use SPI, UART, Analog, PWM and/or I2C. All power is handled by the board. The Click Sensor Hub board allows the students to focus on the code and leave all the complicated wiring to the hardware. **Fig. 1** below shows a high-level diagram of how the Click Sensor Hub board connects.

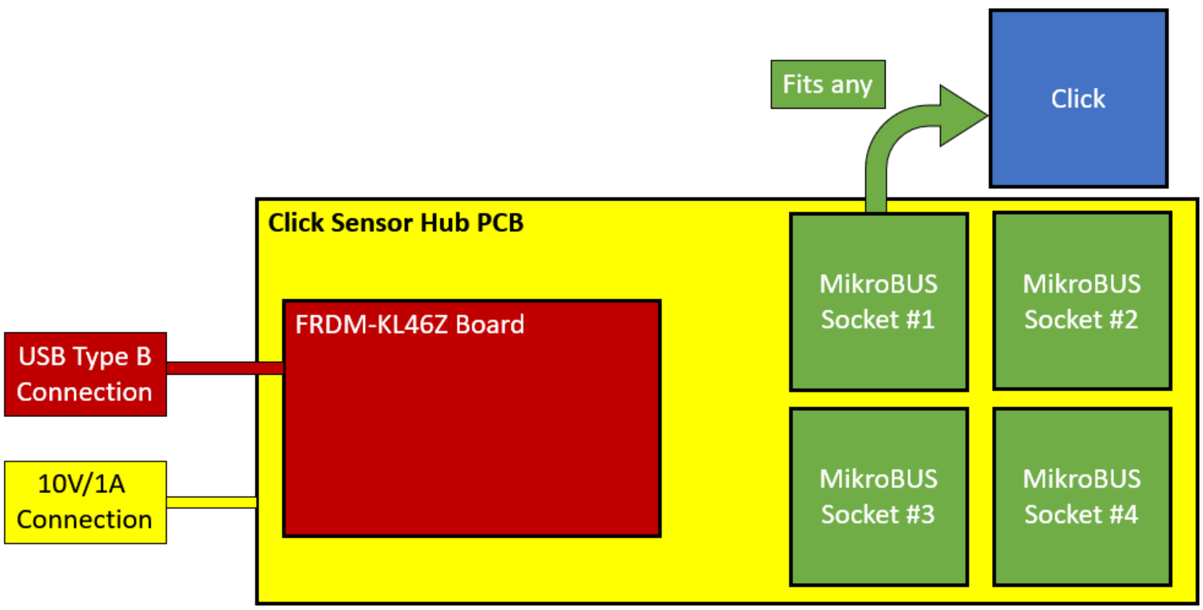

Fig. 1. System level diagram of Click Sensor Hub. Blocks highlighted in yellow were designed for this project.

5 PROGRESS TOWARDS A SOLUTION

5.1 Design Decisions

There have been many iterations of the project. Most have been hardware iterations but there have been some software changes as well. Starting with the hardware decisions, the initial design for the board had the FRDM-KL46Z in the middle and a MikroBUS socket in each of the corners. A schematic for the old design can be seen in **Fig. 2** below.

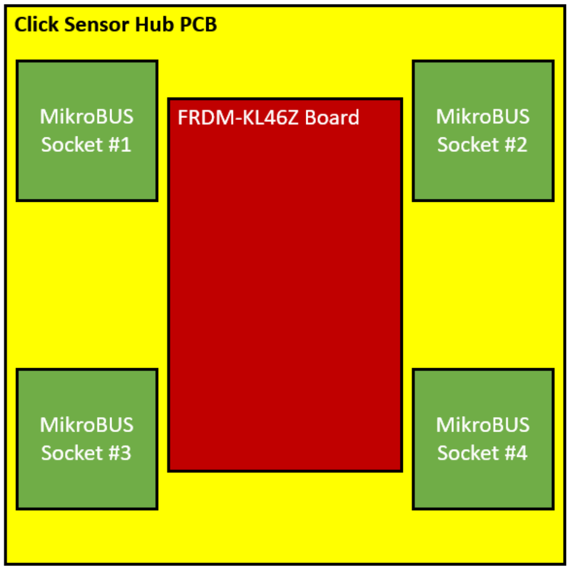

Fig. 2. Initial PCB Design with MikroBUS Sockets in all corners. Blocks highlighted in yellow were designed for this project.

The faults with this approach were mostly due to the layer constraints for the PCB. It was decided early on that the PCB would have a maximum of 2 layers. For the initial design, this caused many wiring issues with wires taking very long detours to reach their destination. This eventually led to the final design which is what was shown in **Fig. 1**. The MikroBUS sockets being in proximity greatly simplified the wiring.

In addition to changing the layout of the PCB, there have also been changes to ICs included in the PCB board. Initially, the Click Sensor Hub board included a 3:8 encoder for the interrupts, a 2:4 encoder for the SPI channels and 1 UART to 2 SPI chips for the UART channels in each of the MikroBUS sockets. This was later removed due to programming and soldering issues the team ran into. In the new version of the Click Sensor Hub board, the 2:4 encoder for the SPI CS was replace with 4 digital out pins, the 3:8 encoder for the interrupter was removed and the a 1 UART to 2 SPI chips were replaced with 4 unique UART channels. An illustration of what was removed can be seen below in **Fig. 3**.

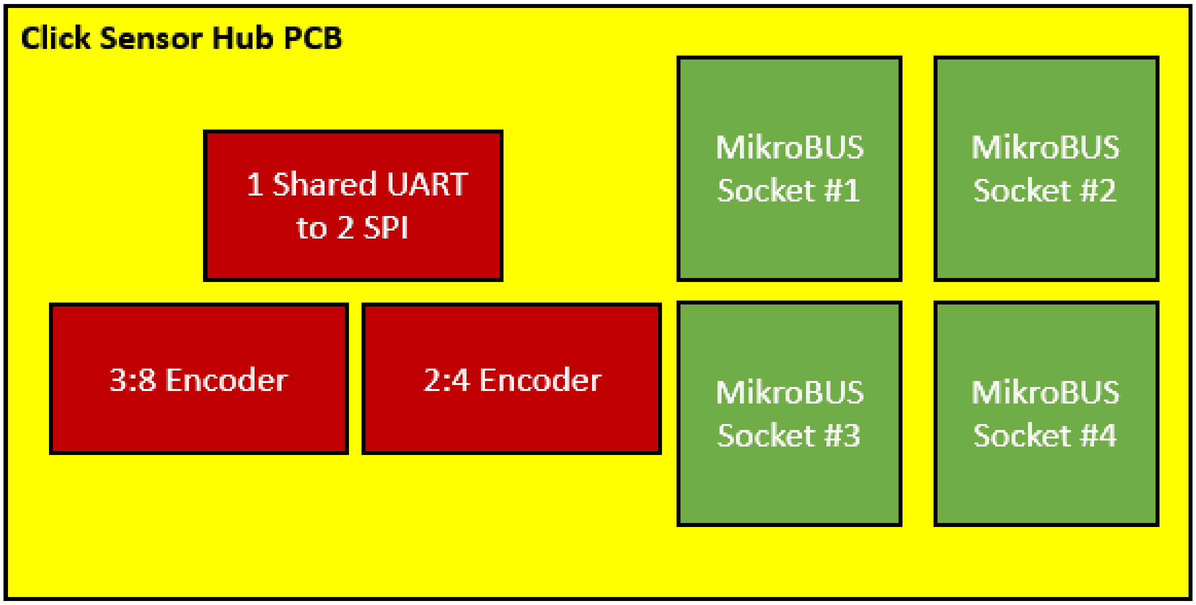

Fig. 3. Click Sensor Hub removed components in final iteration. Removed components for final iteration of PCB design are highlighted in red.

The software also went through many iterations. Initially, the design had many individual classes for each of the Clicks. This was done with the goal to creating a Click Sensor Hub library that could be included in the programs the students made. However, this approach ended up taking too much memory and was unnecessary for what the project meant to achieve. Instead, the Mbed code was simplified to one or two functions per click. This shows anyone who sees the code how to assign the correct pins and what functions to use to communicate in the Mbed compiler.

5.2 Design Approach

The design approach was mostly accomplished thanks to the input and advice of Dr. William Stapleton and Dr. Kevin Kemp. The Click Sensor Hub team meets regularly with them and discusses what decisions they have made throughout the week as well as the results they have produced.

The three engineering students working on the project meet every Monday and Wednesday at the lab to test boards and code in the Texas State University labs. It is important to test each of the decisions made due to products not always performing as the documentation says. A good example is the work done on the Alcohol click. The Alcohol Click measures alcohol levels in the air with analog communication. Before connecting the Click to the board, the team met at the lab and tested the output voltages of the click sensor and found that it produced a 4V reading, which would have fried the FRDM-KL46Z. This example is one of the reasons for which every click is tested for voltage levels before being connected to the board.

The general approach for the Mbed code was to approach each of the clicks individually. The code has a switch function that can select any of the clicks and perform the respective task. The only argument that needs to be specified is the Socket and Click Selection. An example of how the GUI handles this approach can be seen in ***Fig. 4***.

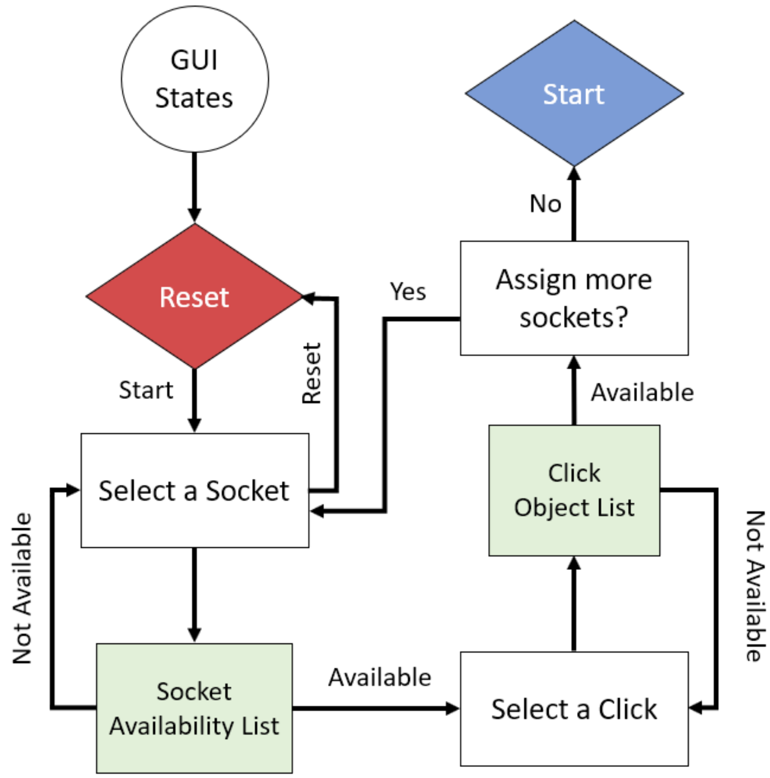

Fig. 4. How FRDM-KL46Z Mbed GUI handles Click and socket selection.

Towards the end of the semester some changes were made to the design that simplified the UART and SPI connections. In the past, the way UART was being handled was with a UART to SPI chip. Unfortunately, this proved to complicate the soldering and programming work too much for the project. As such, the UART to SPI IC was discarded and replaced with 4 straight connections to each of the UART channels on the FRDM-KL46Z. Doing this also freed up 2 Digital-Out pins that were used to get rid of the 2:4 decoder that was being used on SPI. Instead of a 2:4 decoder, the new board design simply has 4 select lines for each of the SPI connections in the MikroBUS sockets.

As for the synchronous aspect of the code, the 4 mikroBUS standard devices had to be constantly switching in a while loop created in the FRDM-KL46Z code for the Mbed compiler. The devices do not run simultaneously, but the switches from one device to the other can be as fast as the FRDM-Kl46Z can handle. Meaning it become dependent on the clock speed which can be overclocked if the user desires it. ***Fig. 5***. below shows how the FRDM-KL46Z code handles switching between Clicks once connected to the Click Sensor Hub board.

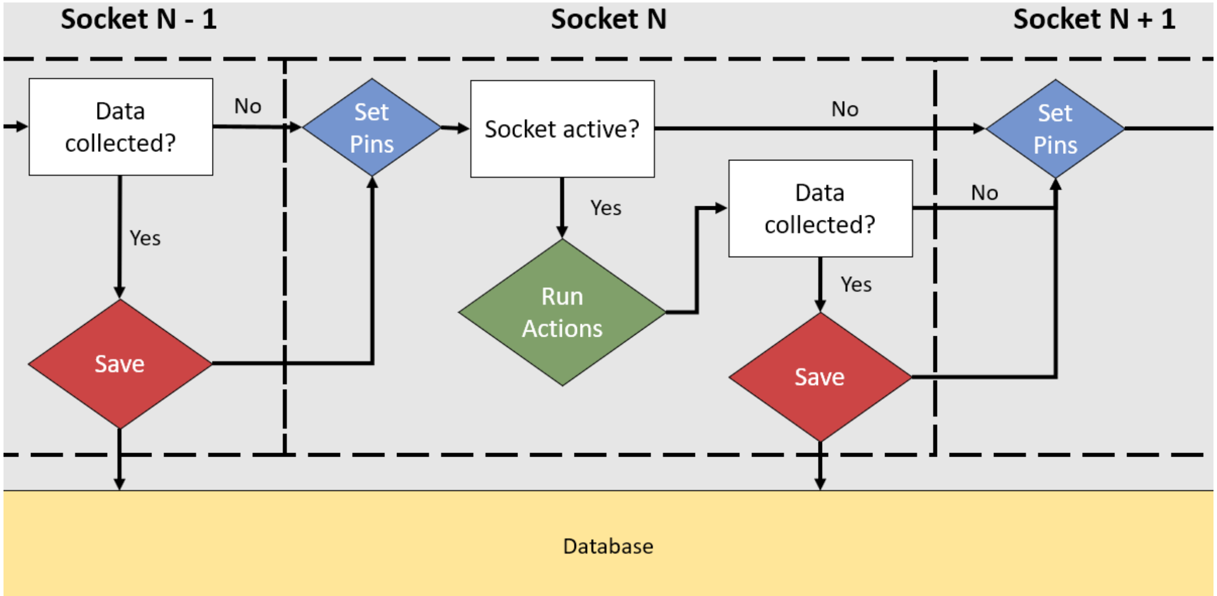

Fig. 5. Loop for FRDM-KL64Z to switch between the different Click Sensors attached to the Click Sensor Hub board. This is meant to approach a simultaneous behavior in which all the Clicks are running at the same time when the switches from one Click to the next

5.3 Project Approach

The Click Sensor Hub project was broken up into two major milestones. The PCB and the FRDM-KL46Z code for the selected Clicks. There was also a stretch goal of making a website to gather all the necessary information to utilize the project. During the first semester focus was on getting the hardware aspect of the project finished. The Click Sensor Hub board ran through many iterations. Even when the design of the board was finalized, it still needed to be tested and the results of these tests resulted in the need for more iterations of the board.

The code for the clicks could be tested without the Click Sensor Hub board. This meant that progress on the code has been going on throughout all stages of the project. Additionally, the code for the Clicks can be worked on individually for each Click. This means throughout the project goals have been set for testing and validating each of the Clicks by certain dates. ***Fig. 6***. below displays how the FRDM-KL46Z interpreted the readings from the 4 MikroBUS standard sockets. It highlights how, from the KL46Z perspective, how many pins the code was dealing with.

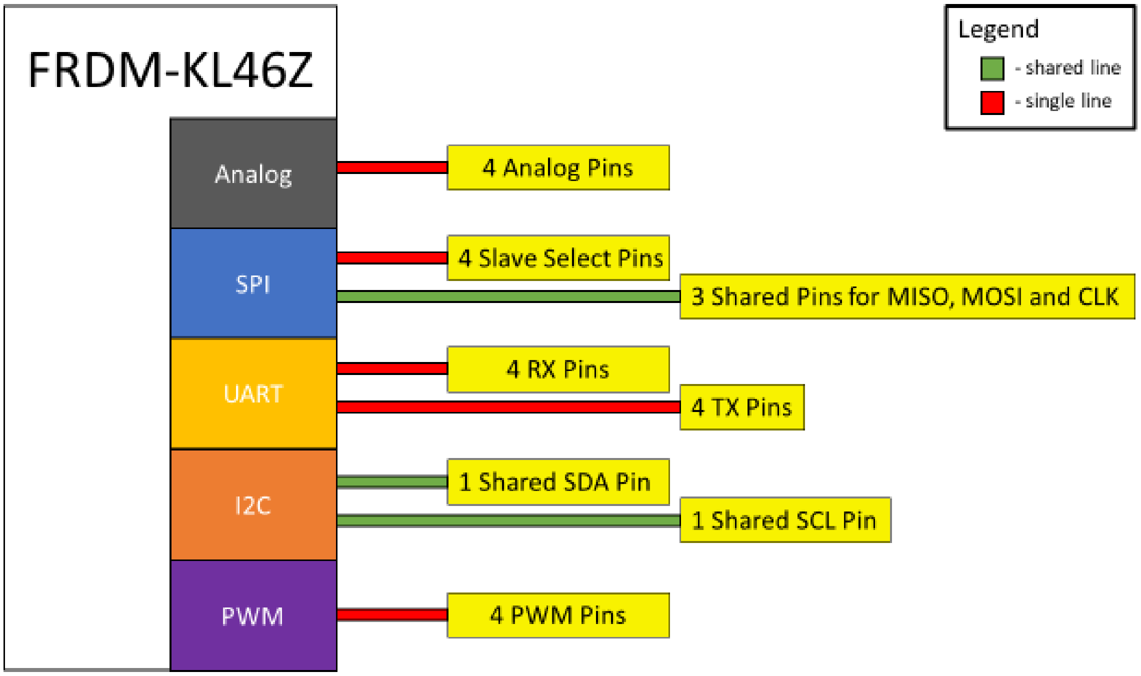

Fig. 6. FRDM-KL46Z pin readings from 4 MikroBUS standard sockets abstraction. The yellow boxes highlight all the pin assignments that were necessary for writing the code in the Mbed compiler.

Work on the website has been done mostly in the week the team waited for the PCB to arrive. At the end of the semester all the data was collected and placed in the correct tab. Links to GitHub and Eagle files were also made available.

5.4 Engineering Standards

Table 1. Applicable Standards

Title	**Application**	**Relevance**
mikroBUS Standard	Four mikroBUS sockets on PCB	PCB Design

5.5 Progress Towards Goals

All initial goals have been completed. All necessary data has been recorded. All Clicks have been tested. The board has been tested. All that is left is to post Senior Design Day results to NXP forums as per the agreement with Dr. Kemp.

5.6 Verification

All tests were performed by 2 or more teammates before being recorded into official documents. Tests on PCB boards were done on multiple boards (at least 1 board per teammate for every test and every iteration of the PCBs). Test for code was reset at least 3 times per test to confirm results. All code tests were performed on at least 2 different days with the same code to ensure correct results.

5.7 Characterization Results

All results were document as specified above in section 5.6. In accordance with the standards set for this project, the results for the Individual Click Validation can be seen in ***Table 2*** and the results for the Click Sensor Hub Board Validation can be seen in ***Table 3***. Tests were generated in accordance to what was documented on the Test Plan and Functional Spec respectively. Finally, ***Table 4*** specifies the results for the Stretch Goal - Website Validation.

Table 2. Individual Click Validation. Detailing the test procedures and the respective results.

Test Case	Test Specifications	Test Results	Compliance
Temp & Hum 2 Click	Board powered by 3.3V connection	Connected board and checked LED light. Measured	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get temperature readings via FRDM-KL46Z code to display on PUTTY	Non-zero reading recorded and displayed on PUTTY	Invalid due to board being discontinued by Mikro
USB UART 3 Click	Board powered by 3.3V and 5V connections	Connected board and checked LED light. Measured	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Successful USB connection via USB UART 3 Click to FRDM-KL46Z	Established PUTTY connection via USB UART 3 Click	Fail
Color 5 Click	Board powered by 3.3V and 5V connections	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages in respective pins measured to be below 3.3V threshold	Pass
	Get RGB readings via FRDM-KL46Z code to display on PUTTY	Non-zero reading recorded and displayed on PUTTY	Fail

Bar Graph 2 Click	Board powered by 3.3V and 5V connections	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Cycle Bar Graph Click through set pattern	Pattern set and displayed on Click	Pass
Accel 5 Click	Board powered by 3.3V connection	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get x, y, z coordinate acceleration readings from Click	Non-zero reading recorded and displayed on PUTTY	Fail
Gaussmeter Click	Board powered by 3.3V connection	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get x, y, z magnetic field readings from Click	Non-zero reading recorded and displayed on PUTTY	Pass
Light Ranger 3 Click	Board powered by 3.3V connection	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get distance readings from Click	Non-zero reading recorded and displayed on PUTTY	Pass
Alcohol Click	Board powered by 5V connection	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage	Voltages measured to be unsafe. Measured at 4.2 volts peak despite tweaking variable resistor	Fail, Click not safe to use

	should be above 3.3V	to max value.	
	Get alcohol level reading from Click	Non-zero reading recorded and displayed on PUTTY using a resistor and a breadboard, not tested on Click Sensor Hub board due to damage it would cause FRDM-KL46Z	Invalid due to not being safe for board
Air Quality Click	Board powered by 3.3V and 5V connections	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get air quality level reading from Click	Non-zero reading recorded and displayed on PUTTY	Pass
microSD Click	Board powered by 3.3V connection	Connected board and checked LED light	Pass
	Ensure safe connection to FRDM-KL46Z, no feedback voltage should be above 3.3V	Voltages of respective pins measured to be below 3.3V threshold	Pass
	Get data from SD card to FRDM-KL46Z via Click board	Number value successfully read from text file	Pass

Table 3. Click Sensor Hub Board Validation. Detailing the test procedures and the respective results.

Test Case	**Test Specifications**	**Test Results**	**Compliance**
Socket #1			Pass
(AN) Analog	Test Analog Click on Socket	Putty output achieved on selected socket with Air Quality Click	Pass
(MISO/MOSI) (CS/SCK) SPI	Test SPI Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(RX/TX) UART	Test UART Click on Socket	Serial connection on computer via selected socket	Pass
(SCL/SDA) I2C	Test I2C Click on Socket	I2C connection displayed data on PUTTY terminal using Temp2Hum Click via the selected socket	Pass

PWM	Test PWM Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(+3.3V/+5V) VCC/GND	All four mikroBUS™ sockets have both an optional 3.3V and 5V channel. All four mikroBUS™ sockets are grounded	When PCB is powered with 10v and 1amp. Both the +3.3V and +5V channels display proper voltage output. The GND has 0V output	Pass
Socket #2			Pass
(AN) Analog	Test Analog Click on Socket	Putty output achieved on selected socket with Air Quality Click	Pass
(MISO/MOSI) (CS/SCK) SPI	Test SPI Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(RX/TX) UART	Test UART Click on Socket	Serial connection on computer via selected socket	Pass
(SCL/SDA) I2C	Test I2C Click on Socket	I2C connection displayed data on PUTTY terminal using Temp2Hum Click via the selected socket	Pass
PWM	Test PWM Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(+3.3V/+5V) VCC/GND	All four mikroBUS™ sockets have both an optional 3.3V and 5V channel. All four mikroBUS™ sockets are grounded	When PCB is powered with 10v and 1amp. Both the +3.3V and +5V channels display proper voltage output. The GND has 0V output	Pass
Socket #3			Pass
(AN) Analog	Test Analog Click on Socket	Putty output achieved on selected socket with Air Quality Click	Pass
(MISO/MOSI) (CS/SCK) SPI	Test SPI Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(RX/TX) UART	Test UART Click on Socket	Serial connection on computer via selected socket	Pass
(SCL/SDA) I2C	Test I2C Click on Socket	I2C connection displayed data on PUTTY terminal using Temp2Hum Click via the selected socket	Pass
PWM	Test PWM Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(+3.3V/+5V) VCC/GND	All four mikroBUS™ sockets have both an optional 3.3V and 5V channel. All four mikroBUS™ sockets are grounded	When PCB is powered with 10v and 1amp. Both the +3.3V and +5V channels display proper voltage output. The GND has 0V output	Pass
Socket #4			Pass
(AN) Analog	Test Analog Click on Socket	Putty output achieved on selected socket	Pass

		with Air Quality Click	
(MISO/MOSI) (CS/SCK) SPI	Test SPI Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(RX/TX) UART	Test UART Click on Socket	Serial connection on computer via selected socket	Pass
(SCL/SDA) I2C	Test I2C Click on Socket	I2C connection displayed data on PUTTY terminal using Temp2Hum Click via the selected socket	Pass
PWM	Test PWM Click on Socket	Bar Graph Click had selected pattern displayed on selected socket	Pass
(+3.3V/+5V) VCC/GND	All four mikroBUS™ sockets have both an optional 3.3V and 5V channel. All four mikroBUS™ sockets are grounded	When PCB is powered with 10v and 1amp. Both the +3.3V and +5V channels display proper voltage output. The GND has 0V output	Pass

Table 4. Stretch Goal Website Validation. Detailing the test procedures and the respective results.

Website Validation			
Test Case	**Test Specifications**	**Test Results**	**Compliance**
Website hosted on Cloud Platform	Runs on Desktop or Mobile Platform via internet	Website successfully hosted on the Google Cloud Services	Pass
Website Content includes all necessary code and user files	A random user accessing the website must have access to all necessary documents	User can download code and hardware files from GitHub link to resources tab.	Pass

5.8 Deficiencies

The project deficiencies detected by the team were mostly improvements to the quality of life of anyone utilizing the Click Sensor Hub board. They are described in detail in ***Table 5*** below.

Table 5. System Deficiencies Accompanied by Suggest Solution and Estimated Completion Time

Deficiency	Effect	Solution	Estimated Time for Solve
System does not detect high voltage levels coming from Clicks	FRDM-KL46Z board has potential to be damaged by Clicks	Integrate a system that regulates the output of the MikroBUS sockets	3 months
Board operates with a variable power source	Difficult to people outside of a lab setting to utilize the Click Sensor Hub Board	Integrate battery or USB power to the board.	2 months
Board not fully synchronous, the code must switch between each of the sockets at a specified speed	Clicks that require constant readings or instructions unable to function if more than 2 Clicks connected to the board utilized the same shared channels	Change design to serve a fully synchronous set of Click boards operating on shared channels	12 months

5.9 Iterations and Redefinitions

From SOW:

"The project is to work with the FRDM-KL46Z microprocessor board by NXP, create a Printed Circuit Board (PCB) that connects it to a minimum of 4 Clicks from MikroElektronika and write software that makes the board compatible with at least 10 Clicks. The purpose of the Clicks is to add functionality to Hexi-wear devices by NXP by expanding their sensor capabilities."

Most notable changes from what was initially written in the SOW is the shift in focus from Hexi-wear to an educational tool to be used in Dr. Stapleton's Microprocessors class. The 4 Click minimum was met by the Click Sensor Hub board. The goal of testing 10 Click sensors was also met as described in section 5.7.

Most major iterations of the project happened when creating improvements on the Click Sensor Hub board. The dates in which these changes were made are described in ***Table 8*** in section 7 of this document. The first iteration of the board had the MikroBUS standard sockets on each of the four corners of the board, as can be seen in **Fig. 2**. The second iteration corrected this and placed the MikroBUS standard sockets on the right side as can be seen in **Fig. 1**. Finally, the third iteration got rid of a couple IC chips that were adding functionality but also complicated soldering and coding complexity. The third iteration is described in section 5.1. **Fig. 3**. displays the changes made in the third iteration in a graphical form.

6 CONSTRAINTS

6.1 Budgetary

The limited budget constrained the design to a maximum of 10 Click Sensors purchased and a maximum of 2 layers on the PCB iterations.

6.2 Design Feasibility

Right from the start, the team knew that it would not be possible to test the components that would be placed on the Click Sensor Hub board. As such, each of the Clicks and the FRDM-KL46Z was assumed to work at the specified characteristics on their technical documents. Additionally, all code written for the FRDM-KL46Z would have to be written on the free/online Mbed compiler. The team also recognized that any PCB that was design would have to be ordered from China at the cheapest price possible. This added the risk of receiving defective boards.

6.3 Manufacturability

The PCB manufacturing had to be ordered through online providers due to the lab at Texas State University not having the necessary equipment to print out the board.

6.4 Maintainability

The code written for the Click Sensor Hub board uses the Mbed library which is maintained by Mbed. As for the code for each individual Click, each of the functions was written for the IC contained in each click. The code for each of the Clicks requires no maintenance if the user is working the with the exact Click model specified in the Technical Spec.

6.5 Environmental

The Click Sensor Hub project is not a source of any major environmental concerns. The only real physical product it provides is a PCB board. Any damage to the environment caused by the Click Sensor Hub project is equivalent to the environmental damage of printing out a PCB.

6.6 Health and Safety

Depending on the click being used a person could be exposed up to 1A of current at a 10V maximum voltage. For this reason, it is recommended to take voltage values of pins a person is going to contact before connecting the FRDM-KL46Z or any of the Clicks.

6.7 Social

The only constraints people would run into when trying to make use of the Click Sensor Hub board is a misunderstanding of where to connect the components so that they may communicate effectively. It is not recommended for anyone without previous knowledge of microprocessors to utilize the Click Sensor Hub board without instructions from a capable individual. It is very simple to fry the FRDM-KL46Z or any of the Clicks with incorrect current and voltage values or with incorrect soldering.

7 BUDGETS

The total project budget for the Click Sensor Hub was $500.00 for both semesters. Both major parts orders can be seen in the following ***Table 6*** and ***Table 7*** below. Additionally, ***Table 8*** contains information of budget costs for each of the PCB orders.

Table 6. Parts Order January 25th, 2019

Vendor	Item Description	Part #	Quantity	Price Per	Total
Digi-Key	2:4 Decoder	SN74LVC1G139DCTR	10	$ 0.62	$ 6.19
Digi-Key	Interface Controller	SC16IS752IPW, 128	6	$ 4.14	$ 24.84
Digi-Key	8:3 Encoder	296-33993-5-ND	3	$ 6.19	$ 18.57
MikroElektronika	Temp&Hum 2 Click	MIKROE-3085	1	$ 16.00	$ 16.00
MikroElektronika	USB UART 3 click	MIKROE-3063	1	$ 15.00	$ 15.00
MikroElektronika	Color 5 click	MIKROE-3107	1	$ 16.00	$ 16.00
MikroElektronika	BarGraph 2 Click	MIKROE-3021	1	$ 19.00	$ 19.00
MikroElektronika	Accel 5 click	MIKROE-3149	1	$ 19.00	$ 19.00
MikroElektronika	Gaussmeter click	MIKROE-3099	1	$ 19.00	$ 19.00
MikroElektronika	LightRanger 3 Click	MIKROE-3103	1	$ 24.00	$ 24.00
MikroElektronika	Alcohol Click	MIKROE-1586	1	$ 15.00	$ 15.00
MikroElektronika	Air Quality Click	MIKROE-1630	1	$ 16.50	$ 16.50
MikroElektronika	microSD click	MIKROE-924	1	$ 16.00	$ 16.00
Amazon	Tupperware for Storage	Sistema 1602 Klip It	2	$ 6.49	$ 12.98
Digi-Key	Diode gen	CD1206-S01575	10	$ 0.15	$ 1.52
Digi-Key	Leaded resistor	MFR-25FBF52-52K3	10	$ 0.08	$ 0.80
Digi-Key	Resistor US0805	RMCF0201FT10K0TR-ND	15	$ 0.10	$ 1.50
Digi-Key	Capacitor 10uF	CL21A106KQCLRNC	15	$ 0.11	$ 1.65
Digi-Key	Diode gen	1727-3869-2-ND	5	$ 0.38	$ 1.90
Digi-Key	Indictor	SRN4018	10	$ 0.40	$ 4.03
Digi-Key	Resistor 1k	ESR10EZPF1001	20	$ 0.15	$ 2.92
Digi-Key	Capacitor 22uF	1276-6687-1-ND	20	$ 0.13	$ 2.56
Digi-Key	Crystals 12MHz	490-5581-1-ND	10	$ 0.29	$ 2.90
Spark Fun	Mini pushbutton switch		5	$ 0.95	$ 4.75
				TOTAL	**$ 262.61**

Table 7. Parts Order February 23rd, 2019

Vendor	Item Description	Part #	Quantity	Price Per	Total
Digi-Key	LD2908 DC to DC	LD29080DT33R	**10**	$ 1.30	$ 11.67
Digi-Key	LM2734 AC to DC	LM2734YMK/NOPB CT-ND	10	$ 2.54	$ 22.82
Digi-Key	22pF capacitor	package case 602	20	$ 0.10	$ 1.48
Digi-Key	Capacitor 10nf	package case 602	10	$ 0.10	$ 0.61
Digi-Key	Resistor 10 k ohm	package case 602	10	$ 0.10	$ 0.67
Digi-Key	Resistor 52.3 k ohm	package case 602	10	$ 0.35	$ 3.00
Digi-Key	Capacitor 10uF	package case 602	20	$ 0.18	$ 2.58
Digi-Key	Crystals 12MHz	5*3.2 4pads	10	$ 0.67	$ 11.26
Digi-Key	8:3 Encoder	300 *7,4 Through Hole	10	$ 0.43	$ 3.71
Digi-Key	Interface Controller	SC16IS752IPW, 128	4	$ 4.14	$ 16.56
Digi-Key	Diode gen	1727-3869-2-ND	5	$ 0.38	$ 1.90
Spark Fun	Mini pushbutton switch		14	$ 0.95	$ 13.30
				TOTAL	**$ 89.56**

Table 8. PCB Orders

Vendor	Item Description	Date	Quantity	Parts Cost	Shipping Cost
HK WEIKU TECHNOLOGY	2 Layer PCB	02/01/2019	10	$ 37.00	$ 23.00
JLCPCP	2 Layer PCB	02/10/2019	5	$ 11.96	$ 23.00
JLCPCP	2 Layer PCB	03/29/2019	5	$ 12.02	$ 23.00
				TOTAL	**$ 129.98**

8 WORK SCHEDULE

The work schedule was made early in the first semester of the project and although the dates may have been pushed back or some of the tasks finished early, the progress was made overall in the order in which it was planned. ***Table 9*** below describes

Table 9. Click Sensor Hub work schedule timeline

Task	Assigned to	Progress	Start	End
Fall 2018 Deliverables		100%	9/10/18	1/22/19
Set up SharePoint site. Organized necessary folders and uploaded relevant documents.	Alfonso	100%	9/10/18	9/12/18
Gathered team suggestions into an easy to read format to present for our sponsors.	Dylan	100%	9/12/18	9/17/18

Listed Sponsor Concerns in one concise document to discuss in meeting.	Mohamed	100%	9/12/18	9/17/18
Set up GitHub and software for online meetings.	Alfonso	100%	9/12/18	9/17/18
Outputting basic “Hello World” program on MBED compiler.	Dylan	100%	9/12/18	9/17/18
Make a list of clicks that will be used for projects with reasoning.	Mohamed	100%	9/12/18	9/17/18
Coordinate Hardcopy of Statement of Work	Alfonso	100%	9/10/18	9/24/18
Begin Initial PCB Design complying with the mikroBUS standard	Mohamed	100%	9/24/18	9/30/18
Begin initial Mbed library design at very high level	Dylan	100%	9/24/18	9/30/18
Coordinate Hardcopy of Functional Spec	Alfonso	100%	9/25/18	10/15/18
Initial Design PCB Finalized	Mohamed	100%	10/15/18	11/1/18
Initial Design for MBED Interface Finalized	Dylan	100%	10/15/18	11/1/18
Coordinate Initial Design Review Presentation	Alfonso	100%	10/15/18	10/23/18
Coordinate Hardcopy Updated Spec	Alfonso	100%	10/22/18	11/5/18
Order PCB to be printed	Mohamed	100%	10/20/18	11/15/18
Design for Initial Website Layout	Alfonso	100%	11/1/18	12/1/18
Coordinate Hardcopy of Labor Cost Schedule	Alfonso	100%	11/5/18	11/19/18
Testing PCB	Mohamed	100%	11/15/18	12/1/18
First Draft of Poster for Review	Mohamed	100%	11/12/18	11/26/18
Coordinate Hardcopy of Test Plan	Alfonso	100%	11/16/18	11/30/18
Second Design-Manufacturing Cycle for PCB	Alfonso	100%	12/1/18	1/15/19
Winter Break	Team	100%	12/14/18	1/22/19
Spring 2019 Deliverables		100%	1/16/19	5/20/19
Complete Signal reading library with interface class using Mbed	Dylan	100%	1/16/19	2/16/19
Full functionality test of I/O with 10 Clicks on functioning PCB	Mohamed	100%	1/16/19	2/16/19
Initial Design for Website with HTML and CSS	Alfonso	100%	1/16/19	2/16/19
Optimize Mbed code and test with all Clicks	Dylan	100%	2/16/19	3/29/19
Gather sample data from Clicks	Mohamed	100%	2/16/19	3/29/19
Implement Website Functionality	Alfonso	100%	2/16/19	3/29/19
Full PCB and Clicks functionality test	Mohamed	100%	3/3/19	4/16/19
Full Mbed code functionality test	Dylan	100%	3/3/19	4/16/19
Full Website code functionality test	Alfonso	100%	3/16/19	4/16/19
Full Project functionality test	Alfonso	100%	4/17/19	5/4/19
Final Poster Review	Mohamed	100%	4/17/19	5/4/19
Final Presentation Preparation	Dylan	100%	4/17/19	5/4/19
Senior Design Day	Team	100%	5/5/19	5/5/19
Post descriptions reports and source code in Mbed and NXP community forums	Alfonso	100%	5/6/19	5/9/19

9 PERSONNEL INTERACTIONS

9.1 Teamwork

Working with microprocessors meant that the large task of completing the Click Sensor Hub Project was able to be split into many daily/weekly/monthly goals that all team members gave input on and contributed. However, there were major project milestones that each member was ultimately responsible for. They are as follows:

Alfonso:

- Activity and resource planning for meeting deadlines
- Document Full Functionality Test
- Mbed code to interfacing between board and sockets
- Stretch – Front/back end design for website
- Stretch – Manage cloud hosting for website

Dylan:

- Mbed code for interfacing between board and sockets
- Presentation, poster, user guide and T-Shirt design
- Document 10 Click Validation Test
- Stretch – Website Design (CSS/HTML)

Mohamed:

- PCB design/edits in Eagle CAD
- Document Hardware Functionality Test
- Soldering prototype boards
- Stretch – Instructional web articles for hardware usage/testing

9.2 Mentorship

The Click Sensor Hub project owes many thanks to its faculty advisor at Texas State University, Dr. William Stapleton, and its Technical Mentor, Dr. Kevin Kemp. Without their continuous input throughout both semesters, the project would not be what it is today. Notably, Dr. Stapleton has met with team almost every Monday and Wednesday since the first semester to help guide our work of the week.

A good example of how Dr. Stapleton helps the project is he helped the team troubleshoot the Bar Graph Click for over an hour when the code was giving wrong results. At the end of the session the code had been worked out and all that was left was testing and validation.

A good example of how Dr. Kemp helps the project is he met with the team twice in the NXP offices to discuss the progress of the project and give us a small tour of the facilities to see how real-world companies handle similar projects. Dr. Kemp also always gives ample feedback on presentations and technical documents.

10 ETHICS

In accordance with the first guideline in the IEEE Code of Ethics this project maintained a focus on the “safety, health, and welfare of the public” by making sure test the design for any flaws that might have caused harm to a user of the product. It also provided “honest and realistic in stating claims or estimates based on available data” in all its documents. Of course, the team has not accepted any form of bribery or partaken in discrimination amongst any of its members (most of whom are foreigners).

The same statements discussed for the IEEE Code of Ethics apply for the NSPE Code of Ethics. In accordance with article I of the NSPE Code of Ethics, the Fundamental Canons, the team has created a safe to use product that looks out for “safety, health, and welfare of the public”. No one individual on the team has caused any environmental damage or otherwise that could suggest they have not conducted “themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession”.

11 SUMMARY & CONCLUSIONS

It is the opinion of the Click Sensor Hub team that this project can be considered a success. Overall the team set out 3 major milestones and it accomplished them. A more detailed version of the of individual tests and results can be seen in ***Table 2***, ***Table 3*** and ***Table 4***. The major milestones of the project are listed below in ***Table 10*** as well the results of testing those milestones seen in ***Table 11***.

Table 10. Courses objectives as defined in the Statement of Work.

#	Objective
1	Create a board that connects 1 FRDM-KL46Z to 4 MikroBUS standard sockets
2	Write necessary code for 10 different Clicks to interact with FRDM-KL46Z via the board created in the first objective
3	Power 4 simultaneous MikroBUS standard sockets via 3.3V and 5V channels provided by a power source that takes 10V/1A
4	Create a user guide that details how to implement and make changes to the project
5	Stretch Goal – Create cloud hosted website that compiles all the necessary project information in one place.

Table 11. General tests and results of objectives described

Objective #	Test	Result of Requirements	Status
1	Document Section 5.7, ***Table 3***	All tests passed	Pass
2	Document Section 5.7, ***Table 2***	7/10 tests passed	Partial
3	Document Section 5.7, ***Table 3***	All tests passed	Pass
4	Document Section 5.7, ***Table 4***	All tests passed	Pass
5	Document Section 5.7, ***Table 4***	All tests passed	Pass

Overall, the project met all its critical requirements to be considered a success. Some of the Click did not meet preferred requirements but this was expected and planned for in advance. The results all met a desired level of accuracy and honesty in accordance with IEEE and NSPE Codes of Ethics. The Click Sensor Hub Team provided results that meet over 100% of the objectives due to meeting of Stretch Goals in addition to required goals.

12 DISCUSSION

12.1 Academic Preparation

This project would have been near impossible without the years of knowledge acquired at Texas State University. Most notably the selected courses the team agreed helped the most can be seen below in ***Table 12***.

Table 12. Courses teammates agreed were most useful for completing the Click Sensor Hub project

Course No.	Core knowledge	Specific knowledge incorporated by team
EE 3350 (Electronics I)	Design and analysis of active devices and equivalent circuits	Useful for testing different connection points across design for correct voltage readings.
EE 3420 (Microprocessors)	Principles of operation and applications of microprocessors	Understanding of SPI, I2C, UART, Analog and PWM channels
EE 4352 (Introduction to VLSI Design)	Analysis and design of CMOS integrated circuits	Used in design of PCB to understand constraints and requirements
EE 4370 (Communications Systems)	Transmission of signals through linear systems, analog and digital modulation, and noise	Used for stretch-goal of website design. Knowledge helped with setup of Cloud hosted website.

12.2 Lessons Learned

Many lessons learned in resource as well as time management. Perhaps the most technical lessons learned are as follows:

- Testing of the Click boards should have been done sooner, perhaps in the first semester due to the fact the board did not need to be finished to test the code.
- When having issues with any chip manufactured by a large company, give them a call. They will have a technical support team willing to help you.
- Each teammate should have been given 1 or 2 Clicks at the most and they should have been responsible for all the added functions given to them.

12.3 Soft Skills

The team learned as whole how to present their progress in front of a crowd of people. Over the course of the semester every member learned from what the instructors and other students though of their presentations and made changes to respond accordingly. One important lesson from this was explaining our project in simpler terms. Initially for presentation, the audience would give feedback that Clicks were confusing or that it was not very clear what the Click Sensor Hub project did. This was corrected progressively throughout both semesters.

12.4 Schedule Deviations

The major deviation in the project was due to ordering the PCB to be shipped during Chinese New Year. The festivities delayed the PCB by over 2 weeks. In addition, once it arrived the team tested it and found that newer versions needed to be ordered.

12.5 Staffing

Having one less team member than other teams affected productivity. In addition, a large part of the project was coding and only one member on the team was a Computer Engineer. The Computer Engineering major was also the project manager, so a lot of the coding work was being done by a person that already had his hands full most of the time. As for the PCB design, the team member in charge of that was very capable due to having prior experience but without that experience there is no coursework at Texas State University that would have prepared him. PCB design should, in our opinion, be taught at some point in the Electrical Engineering curriculum.

12.6 Final Observations

If this project started again today, the PCB design would obviously be the last iteration that is currently being used. In addition, each team member would have been given at most 2 Clicks to work on. Most Clicks would have been SPI, Analog or PWM since those were the easiest to understand and operate.

13 ACKNOWLEDGMENTS

The authors wish to acknowledge Texas State University for providing a testing grounds for all calculations as well as many years of education and hard work that gave the authors the capacity to accomplish everything written down. In addition, special thanks to Dr. William Stapleton for providing guidance throughout all stages of the product. Additionally, special thanks to Dr. Kevin Kemp for also providing guidance and letting us meet with him at NXP offices. Without both individuals the project would not have what it is today.

14 REFERENCES

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