BOEING
NFC PART VERIFICATION SYSTEM

Design Review

ECE 445

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I. Introduction

i. Statement of Purpose

Near field communication (NFC) is a technology that is relative to Radio Frequency Identification (RFID), Bluetooth, and WIFI technologies. The major difference between these technologies and NFC is that NFC readers work at short-ranges about 4 inches. Regardless of the short-range, NFC has a big advantage compared to other technologies as it does not always require specialized devices. Nowadays, NFCs are embedded in smartphones with NFC tags which allows access to many functionalities. The current part-verification system used by Boeing is based on RFID, which is costly and functions read-only. For this reason, Boeing desires to develop a prototype system that can show the value of NFC by providing solutions in more than one case study. In order to digitalize paper trails and legacy systems; we established two case studies which could be gathered under the roof of part and inventory tracking.

First case study would be industrial process tracking. This study would make use a microcontroller and a backend server system to log information about whether the part has been through an industrial process or not. In particular, this case study would focus on heat treatment and determine whether the part has been heat treated in any way or not, and the particular details about the treatment. The NFC tag would be used to access this data later on in the part's life cycle to accurately determine if anything might be wrong with it.

Second case study would be to track and validate parts to make sure they haven't been tampered with. This case is more hardware intensive as it makes use of a sensor bundle to log important information about the part. It would consist of two main blocks, namely the data logger and the data transmitter blocks. The logger would consist of the sensor bundle, the microcontroller and the memory to continuously log data, while the transmitter would send that information to the backend server, when it is turned on.

In short, our goal in project is to satisfy the wants and needs of Boeing by focusing onto accurate, easy-access, and effective usage of NFC in part and treatment verification. Our NFC system will provide two-way communication between the reader and tags, and establish read and write functions. Furthermore, the project will satisfy the requirements for accuracy, easy-access, and cost efficiency by cutting down the required equipment to be mainly smartphones and tags which contain specific information about a particular part.

ii. Objectives

Goals

- Ensuring the demands of Boeing are met.
- Establish the two-way communication between NFC reader and NFC tags.
- Demonstrate applicability to the two case studies that were presented
- Provide additional modulation in the form of sensor bundles.
- Prove that NFC has the ability to take over the current legacy systems

Functions

- Wireless communication between NFC reader (smartphone) and tags
- Software application system to track data from tags.
- Custom levels of accessibility to data on tags.
- Backend server system to store data

Benefits

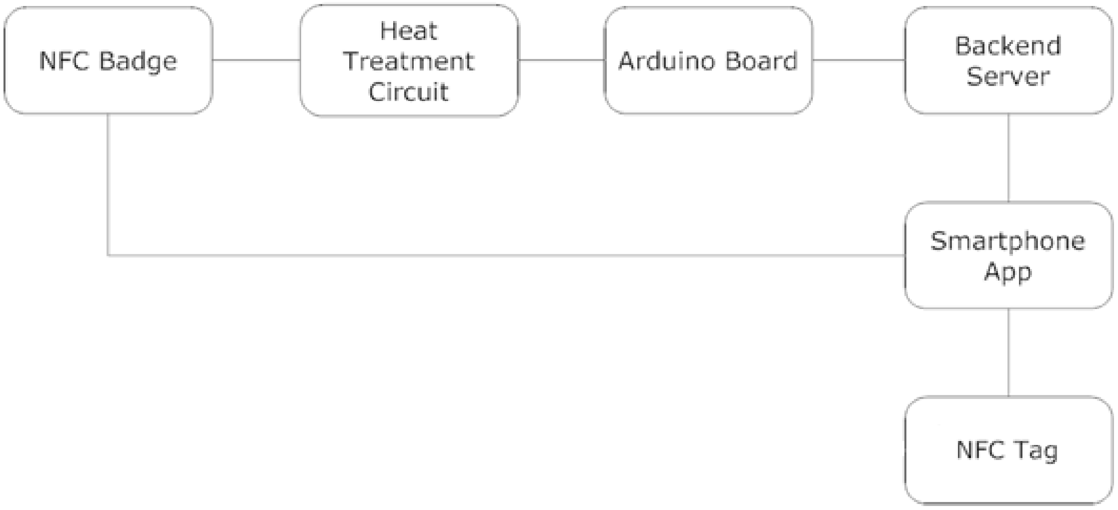
- No need for specialized readers for part verification.
- NFC chips provide more security than existing RFID technologies
- Cheaper than existing RFID verifications systems.
- Complete digitization of paper trails and ease of access

Features

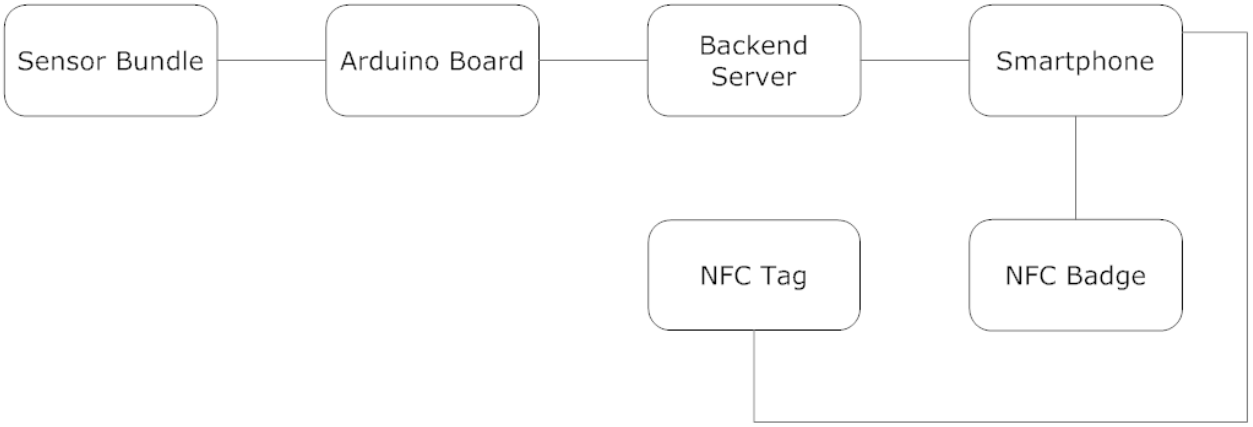
- 13.56 MHz is the operating frequency of the system
- Expected operating range to be between 2cm ~ 5cm.
- Expected bit rate between 106 to 848 Kbit/s
- Android application for our software logging case.

II. Design

i. Overall Block Diagrams



Block Diagram 1: Case Study 1



Block Diagram 2: Case Study 2

ii. Block Descriptions for Case Study 1:

NFC Badge

This block consists of the employee identification badge, which includes an embedded NFC tag. The badge will contain any relevant information about the employee, i.e. credentials. Before accessing the treatment circuit, the employee would scan the badge with a smartphone and make the backend server aware that a part is going to be heat treated by also scanning the tag on the part and following the necessary directions.

Treatment Circuit

This block contains a test circuit to simulate similar conditions to a heat treatment facility at a plant. The circuit itself consists of an analog temperature sensor and a control block which would employ both negative and positive feedback to control the current supply to the heater patch. The sensor is powered with a bench supply of 3.5 V. The control circuit cuts the power supply to the heater patch when the required temperature is reached, using the feedback from the sensors; so that energy wastage decreases.

In order to determine which analog temperature sensor would perform better in this particular application, tests involving a LM335 Texas Instruments Precision Temperature Sensor and a Vishay Components NTC Thermistor. Two circuits were built to test these sensors, as shown in *Figures 1* and *Figure 2*. R1 in *Figure 1* is selected according to the datasheet of the sensor. The ambient temperature is varies linearly with the output voltage across R1, as shown in *Equation 1*.

$$\boldsymbol{T = 100(V - 2.98) - 25 \qquad [°C]}$$

Equation 1: 2.98V is the voltage reading calibrated at room temperature.

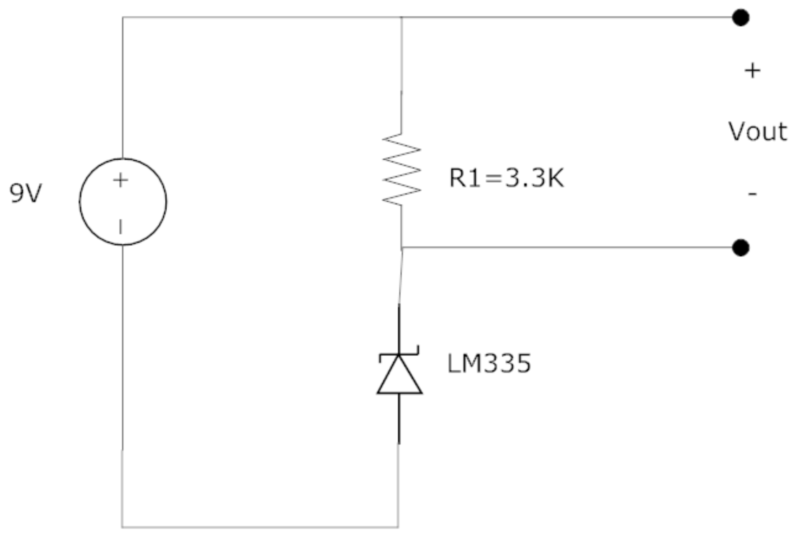


Figure 1: LM 335 Test Circuit Diagram, R1= 3.3kΩ

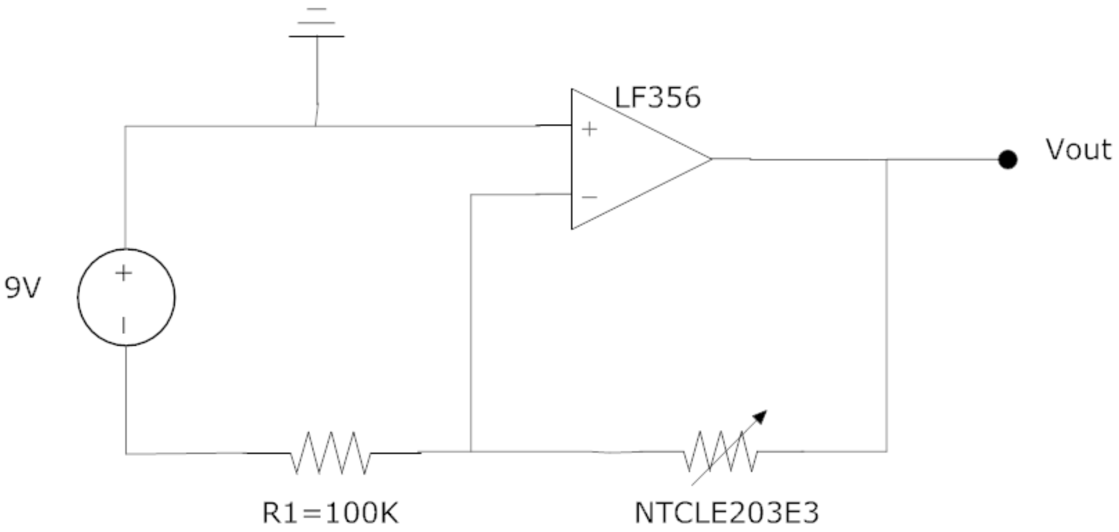


Figure 2: NTC Thermistor Test Circuit

R1 in this case is determined according to the datasheet of the thermistor as its value affects the range of values that R_t can take. This circuit makes use of a simple op-amp inverter configuration, just for ease of measurement. As little or no current goes into the amplifier, all the current will pass through the thermistor. Assuming this current is constant, the output voltage of the amplifier could be determined so that R_t can be determined according to Ohm's Law. Once R_t is known, the temperature reading can be figured out by the following equation.

$$R_T = R_o e^{\beta\left({}^{1}/_{T} - {}^{1}/_{T_o}\right)}$$

Equation 2: To in this case is the calibrated room temperature, beta is given in data sheet

In order to gain some insight about the performances of both of these circuits, 2 tests were run. In the first test both thermistors were cooled down to a certain point and then let to heat back up, simulating a heating experience, while in the second test, in order to see the sensitivity of the sensors, a test subject breathed hot air onto the sensors constantly. *Figures 3* and *Figure 4* show the results of these tests respectively.

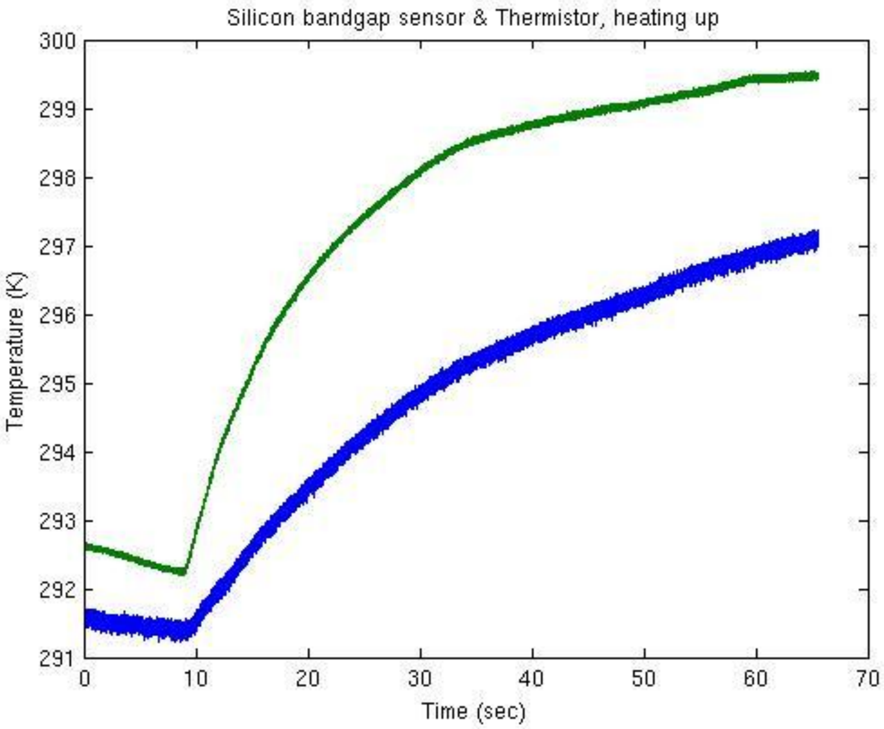


Figure 3: Both sensors heating up, thicker graph is LM335

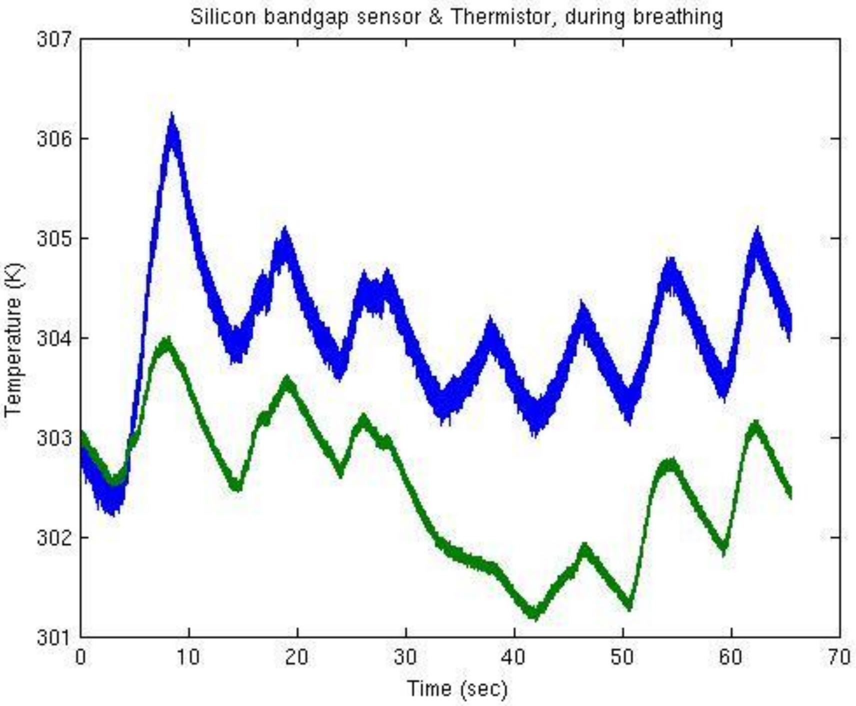


Figure 4: Instantaneous responses of respective circuits, thicker graph is LM335

Since the thermistor has a much quicker response time and it is generally accompanied with less noise, it was selected to be used in the treatment circuit.

Last part of the treatment circuit block is the Arduino microcontroller. This board takes in inputs from two temperature sensors and compares them to a set voltage value that is determined by the user. If the sensor readings are larger than the set voltage value, the expected temperature is reached and the Arduino puts out an output that will turn on a switch that cuts the power off of the heater patch. It also stores temperature readings and sends them to the back-end server via WIFI.

Back-end Server

The back-end server holds information of various natures about the part. In this particular case study, it holds the serial numbers of the parts that are going to be heat treated, and the temperature information that accompanies that part.
The server receives information from the data bridge, stores it to a database, accepts queries from the smartphone application and transmits data to the smartphone. It also has the ability poll a single smartphone or a multitude of smartphones to access data about a particular part.

Smartphone/Smartphone Application

An Android based smart phone application acts as a control unit and a receiver for this case study. This smart phone would be used by an employee to check if a part has been heat treated or not. To access this particular information, the smartphone would scan the NFC tag on the part which contains the part's serial number. The interaction between the tag and the smartphone is based on inductive coupling, as seen in *Figure 3*.

The smartphone then receives the serial number from the NFC tag, and conveys that information to the application. The application then queries the server to access information about that particular tag, which is then displayed on the smartphone screen. If the part has been heat treated correctly, the employee would have the opportunity to write a confirmation label on the tag with the smartphone to further confirm the treatment. If the part has not been treated properly or has not been treated at all, the employee then has the opportunity to perform the necessary actions.

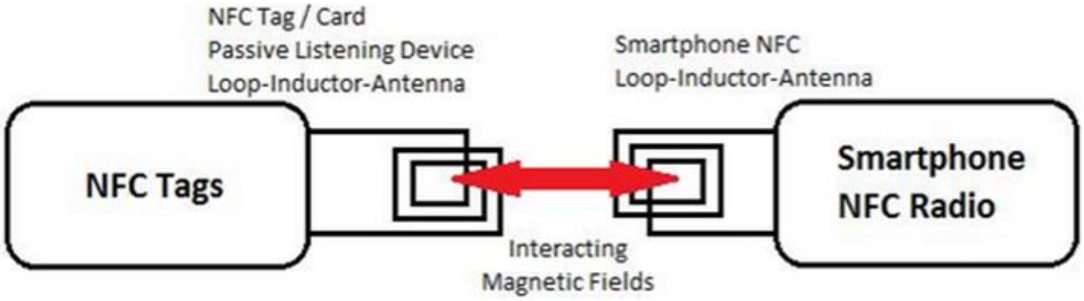


Figure 3: Tag – Phone Interaction [4]

iii. Block Descriptions for Case Study 2:

Sensor Bundle

The sensor bundle consists of a digital temperature sensor and a digital accelerometer. The temperature sensor used for this case study is the Texas Ins. TMP103, which outputs 8 bits of data. The accelerometer that will be used is the Analog Devices ADXL312 which outputs 16 bits of data. The sensor bundle is powered up with a lithium battery that outputs 3.5 V.

The bundle consists of three digital temperature sensors and one accelerometer. Together these sensors will collect data on the environment and movement of the part during the entire transportation process from the supplier to the manufacturing plant of Boeing. The data from the sensors will be logged onto the Arduino memory. To conserve memory space, the data will be logged less frequently when the sensor readings are within the desired ranges but all the data will be recorded when data points indicate conditions outside the expected range.

The total power requirement of the sensor bundle is:

For accelerometer: 3.5V x 0.3mA = 1.05mW
For 3 temperature sensors: 3*(3.5V x 0.085mA) = .8925 mW
Total Power: 1.9425 mW

Arduino Board

The data from the sensor bundle is fed into the Arduino. The Arduino will log this data into the memory component. The data is logged less frequently while the sensor readings indicate desired values but all the data from erroneous conditions will be stored for later retrieval and analysis. The Arduino will also function to send this data from memory to the back-end server via WIFI when the part has reached the Boeing manufacturing site.

NFC Badge

This block consists of the employee identification badge, which includes an embedded NFC tag. The badge will contain any relevant information about the employee, i.e. credentials. Before accessing the information from the Arduino board, the employee would scan the badge with a smartphone to access the smartphone application.

Smartphone/Smartphone Application

An Android based smart phone application acts as a control unit and a receiver for this case study. This smart phone is used by the employee performing the quality check. To access the information, the smartphone would scan the NFC tag on the part which contains the part's serial number. The interaction between the tag and the smartphone is based on inductive coupling.

The smartphone then receives the serial number from the NFC tag, and conveys that information to the application. The smartphone would then be connected to the Arduino with a USB connection to retrieve the data stored in memory to be given to the application. The application would then send the temperature and accelerometer data along with the serial number of the part to the server so all the information can be stored together.

Back-end Server

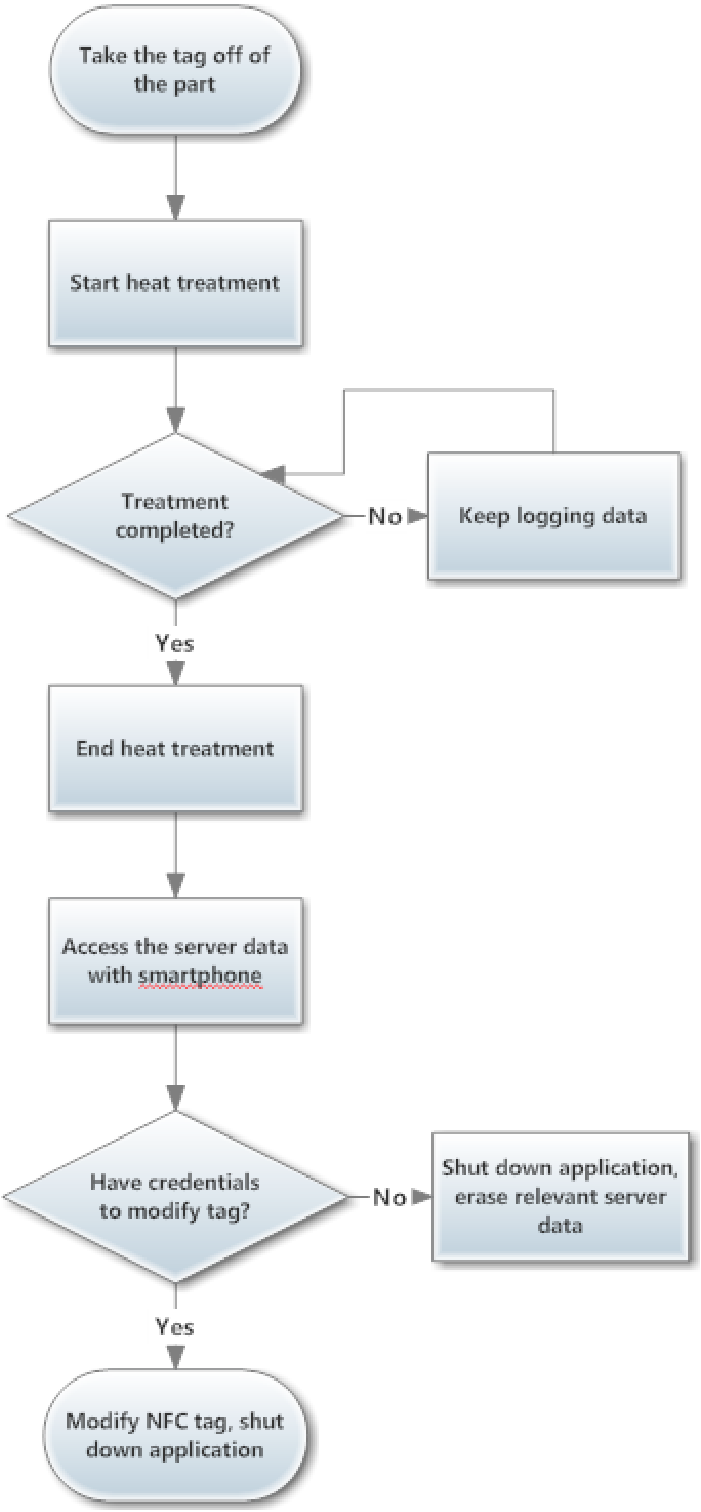
The back-end server holds information of various natures about the part. In this particular case study, the server holds the serial numbers of the parts that have arrived at the manufacturing plant and the data collected from the temperature sensors and accelerometer sent by the Smartphone application. The server will hold also the identification information about the employee who is performing the quality check on the part shipment.

NFC Tag

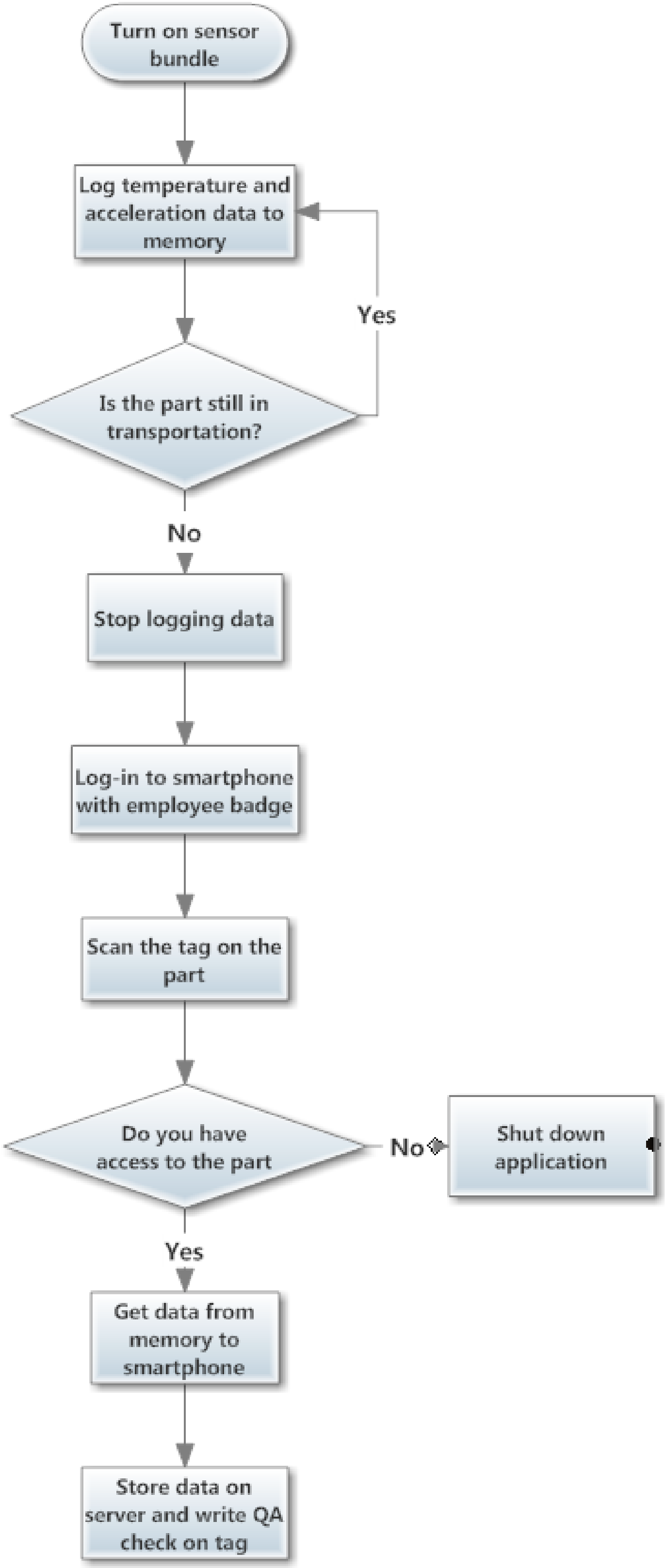
In this case, NFC tag contains the serial number of the part, to let the smartphone send the serial number of the part being checked during the quality assurance process. The smartphone would also write to the tag at the end of the process with a verification that the quality assurance process was completed and the part is okay to be used in the manufacturing plant.

iv. Flow Charts

Flow Chart for Case Study 1:

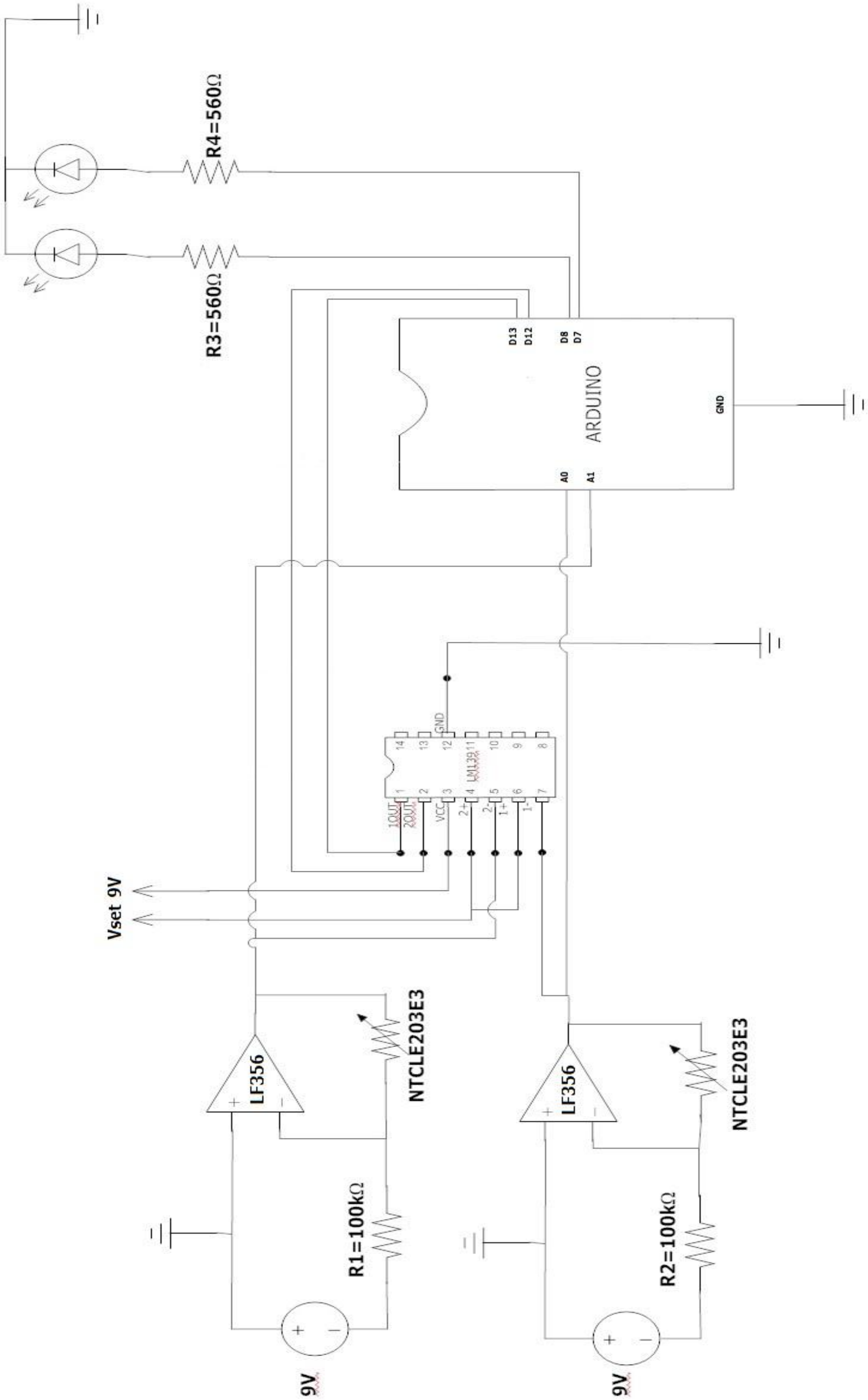

Take the tag off of the part
Start heat treatment
Treatment completed?
No
Keep logging data
Yes
End heat treatment
Access the server data with smartphone
Have credentials to modify tag?
No
Shut down application, erase relevant server data
Yes
Modify NFC tag, shut down application

Flow Chart for Case Study 2:

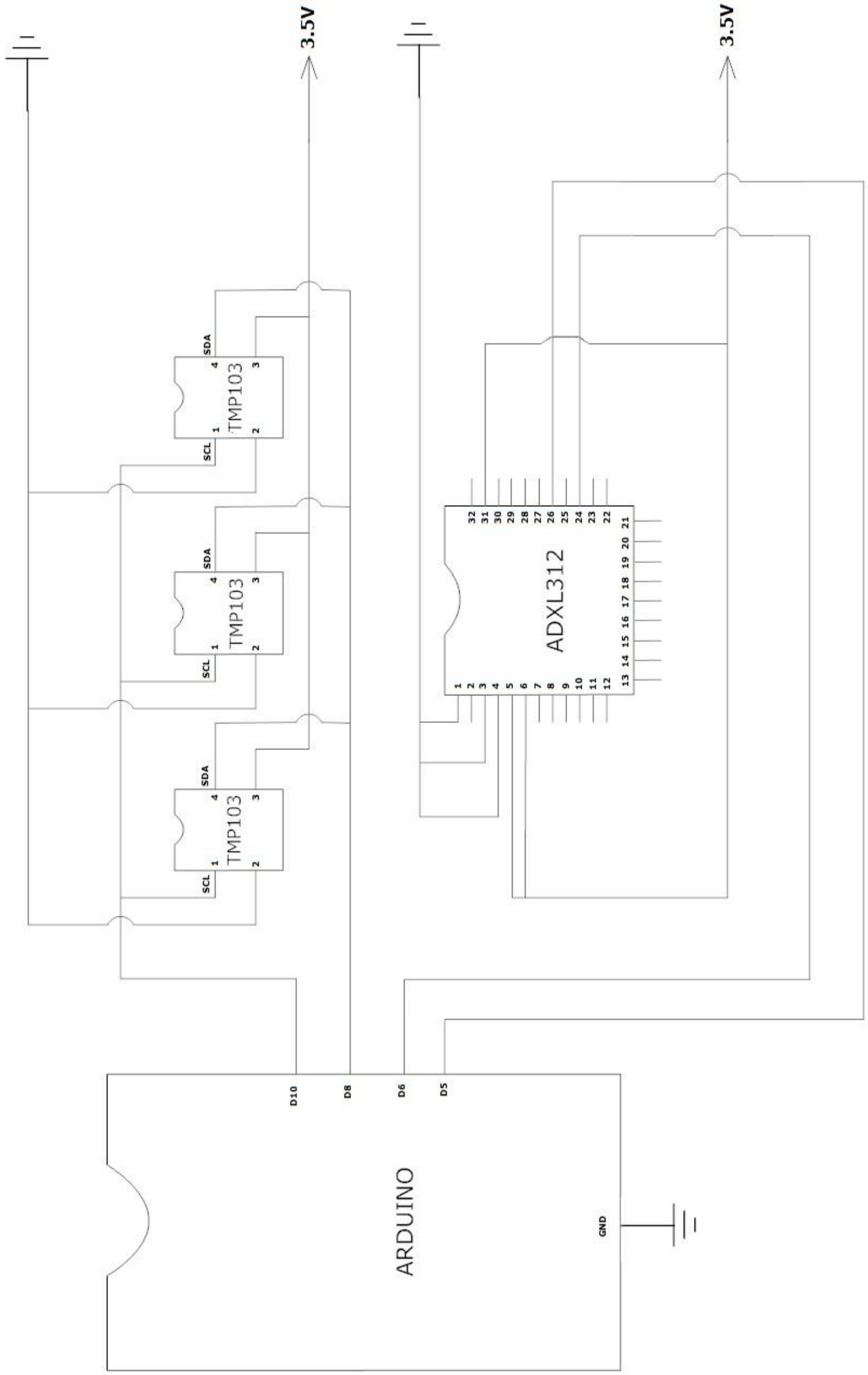

Turn on sensor bundle
Log temperature and acceleration data to memory
Yes
Is the part still in transportation?
No
Stop logging data
Log-in to smartphone with employee badge
Scan the tag on the part
Do you have access to the part
No
Shut down application
Yes
Get data from memory to smartphone
Store data on server and write QA check on tag

v. Circuitry

Circuitry for Case Study 1:



Circuitry for Case Study 2:



III. Requirements and Verification

i. Requirements Summary

Software Application on Smartphone

Create a custom application that is capable of reading data from the tags and writing new data to the tags, as well as accessing the back-end server system to access data about that particular tag.

NFC Tags

Test to see if the tag has both the read and write features when interacting with the Smartphone reader. The tags should be accessible in the range of 2 ~ 5cm.

Arduino Memory

Make sure that the memory has enough store capability to store the amount of required data.

Heat Treatment Circuit

The circuit should be capable of measuring temperatures from 0 to 50 °C in order to successfully demonstrate the model.

Sensor Bundle

The bundle should be capable of measuring temperatures from -40 to 120 °C in addition to vertical and horizontal G's up to ± 3G.

Arduino WIFI Shield

The shield should be able to transmit data wirelessly to the server system without any major time delay, and data corruption.

Arduino Uno R3

Make sure that it is able to control the read and write functions and successfully stores the incoming data.

ii. Verifications Summary

Software Application on Smartphone

Verify that the smartphone is reading the data from the tags and displaying the specifications of the part to the user by testing the smartphone's ability to scan tags.

NFC Tags

Using the smartphone application, verify that the tags are operational and have enough storage capacity for their case scenario.

Arduino Memory

Using the Arduino board both read to and write from the board's memory to determine its functionality and make sure that it has enough store capacity for its designated case scenario.

Heat Treatment Circuit

Test the circuit by applying a hot pack and logging data, to determine the accuracy and to confirm full functionality

Sensor Bundle

Heat the heater patch up to a certain temperature in order to make sure it can effectively simulate a heat treatment facility, and accelerate the circuit to change the G's, in order to determine the accuracy and confirm full functionality.

Arduino WIFI Shield

Send data to the other data bridge to determine latency and verify that the master device is able to acquire data and transmit it to the PC via USB.

Arduino Uno R3

Program the Arduino board to write to and read placeholder data off of the memory and verify that it can convey the data wirelessly to the server system.

iii. Verifications for Case Study 1

Requirements	Verifications
NFC Badge	**NFC Badge**
1. Must be able to store and convey user credentials and employee identification number.	
a) Have 1KB of storage space	a) Store exactly 1KB of data on the tag and use the smartphone to scan the tag again and ensure that 1KB of data has been received.
b) Ability to be accessed in the range of 4cm ±2cm's	b) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.
Treatment Circuit	**Treatment Circuit**
1. Has to be able to simulate a heat treatment facility in a smaller scale, by measuring temperatures between 0 and 50 °C.	
a) **Thermistor** has to be able to detect a temperature range 0 to 50 ± 0.5 °C with an maximum error of 2% (± 1 °C)	a) With a pre-calibrated mercury based thermostat that is accurate to 0.01 °C measure the room temperature. Compare the recorded value with the measured value given by the test circuit in *Figure 2*.
b) **Op-amp** should have a maximum input current of 1nA (±0.1 nA)	b) Using a multi-meter which is accurate to 0.015 mV, measure the input voltage of the op-amp. Determine the input resistance using the same multi-meter. Use Ohm's Law to determine the input current.
c) **Comparator** should be able to take two analog inputs and output a binary string based on the comparison of the two values with a sensitivity of 5mV ± 0.1 mV.	c) Using a multi-meter which is accurate 0.015 mV, measure two analog voltage signals that are identical up to the 3rd digit. Change only one of the inputs by 5mV with the help of the multi-meter and make sure that the comparator can tell which one is greater voltage. Repeat the procedure with a change in the other input.
d) Power Supply has to be capable of putting out 9 ±0.2 volts.	d) Using a multi-meter which is accurate 0.015 mV, measure the output of the power supply.

Arduino Uno R3	**Arduino Uno R3**
1. Has to be able to store and transmit data with high data integrity and a minimum processing rate of data.	
a) Has to be able to read off of and write to its own memory, with a minimum speed of 106 Kbit/s.	a) Program the Arduino to write 1KB of placeholder data and output the number of clock cycles it takes to perform the task. Repeat the same procedure with a read task.
b) Must transmit data wirelessly to the server system with a maximum latency of 30 ± 1ms	b) Ping the server 600 times and average out the latencies in order to make sure the average is below 30 ± 0.1 ms, with a confidence interval of 95%.
c) Must have a maximum error probability of 0.012%, while transmitting data wirelessly.	c) Send 90 packets to the server and compare the received data with the original data, and calculate the rate of errors. Make sure it is under 0.012%.
2. Has to be able to turn on/off power to the heater patch according to the sensor data.	
a) Must be able to interpret comparator output in order to shut down power at 50 ± 0.1 °C.	a) Program the board to output constant voltage readings while heating the heater patch to 50 °C. Determine the exact voltage at which the heater turns off and plug it in to *Equation 2*, and make sure the resulting temperature is 50 ± 0.1 °C.
b) Has to be able to visually display the current state of the treatment with LED's by emitting green light when the heater patch is on and red light when the heater patch is off.	b) Using a multi-meter that is accurate to 0.015 mV, make sure that the board drives the multicolor LED's with 2.0V ± 0.1V for a red emittance and with 3.2 V ± 0.1 V for a green emittance.
Back-end Server	**Back-end Server**
1. Has to be able to poll devices and receive queries from devices with a high data integrity and speed.	
a) Must have a maximum error probability of 0.012%, while transmitting data wirelessly.	a) Send 90 packets to the server and compare the received data with the original data, and calculate the rate of errors. Make sure it is under 0.012%.
b) Must be able to poll devices and receive queries with a maximum latency of 30 ± 1ms.	b) Ping the server 600 times and average out the latencies in order to make sure the average is below 30 ± 0.1 ms, with a confidence interval of 95%.

Smartphone & App 1. Has to be able to wirelessly send and receive data from the server with high data integrity. a) Must have a maximum error probability of 0.012%, while transmitting data wirelessly. b) Must be able to poll devices and receive queries with a maximum latency of 30 ± 1ms. 2. Must be able to access serial numbers on NFC tags and employee badge identification numbers on NFC badges and also update information on NFC tags. a) Ability to access tags in the range of 4cm ±2cm's.	**Smartphone & App** a) Send 90 packets to the server and compare the received data with the original data, and calculate the rate of errors. Make sure it is under 0.012%. b) Ping the server 600 times and average out the latencies in order to make sure the average is below 30 ± 0.1 ms, with a confidence interval of 95%. a) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.
NFC Tag 1. Must be able to store and convey part serial number and QA check results. a) Have 1KB of storage space b) Ability to be accessed in the range of 4cm ±2cm's	**NFC Tag** a) Store exactly 1KB of data on the tag and use the smartphone to scan the tag again and ensure that 1KB of data has been received. b) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.

iv. Verifications for Case Study 2

Requirements	Verifications
NFC Badge	**NFC Badge**
1. Must be able to store and convey user credentials and employee identification number.	
a) Have 1KB of storage space	a) Store exactly 1KB of data on the tag and use the smartphone to scan the tag again and ensure that 1KB of data has been received.
b) Ability to be accessed in the range of 4cm ±2cm's	b) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.
Sensor Bundle	**Sensor Bundle**
1. Has to be able to measure temperature and acceleration and convey that information to the Arduino block.	
a) Capable of measuring temperatures between -40 to 120 (± 0.1 °C) °C.	a) With a pre-calibrated mercury based thermostat that is accurate to 0.01 °C measure the room temperature. Compare that with the output of the digital temperature sensor bundle to verify is tolerance is in the given range.
b) Capable of measuring accelerations up to ±3G's (±0.1G).	b) Conduct a free-fall tests to with a pre-calibrated accelerometer that is accurate to ±0.1 G and determine the exact value of 1G.Make sure that the tolerance is ± 0.1G.
c) Battery has to be capable of putting out 3.5 ±0.1 Volts and 50 ± 10 mA.	c) Using a multi-meter which is accurate 0.015 mV, measure the output of the power supply.

<u>Arduino Uno R3</u> 1. Has to be able to store and transmit data with high data integrity and a minimum processing rate of data. a) Has to be able to read off of and write to its own memory, with a minimum speed of 106 Kbit/s.	**<u>Arduino Uno R3</u>** a) Program the Arduino to write 1KB of placeholder data and output the number of clock cycles it takes to perform the task. Repeat the same procedure with a read task.
<u>Back-end Server</u> 1. Has to be able to poll devices and receive queries from devices with a high data integrity and speed. a) Must have a maximum error probability of 0.012%, while transmitting data wirelessly. b) Must be able to poll devices and receive queries with a maximum latency of 30 ± 1ms.	**<u>Back-end Server</u>** a) Send 90 packets to the server and compare the received data with the original data, and calculate the rate of errors. Make sure it is under 0.012%. b) Ping the server 600 times and average out the latencies in order to make sure the average is below 30 ± 0.1 ms, with a confidence interval of 95%.
<u>Smartphone & App</u> 1. Has to be able to wirelessly send and receive data from the server with high data integrity. a) Must have a maximum error probability of 0.012%, while transmitting data wirelessly. b) Must be able to poll devices and receive queries with a maximum latency of 30 ± 1ms. 2. Must be able to access serial numbers on NFC tags, employee badge identification numbers. a) Ability to access tags in the range of 4cm ±2cm's	**<u>Smartphone & App</u>** a) Send 90 packets to the server and compare the received data with the original data, and calculate the rate of errors. Make sure it is under 0.012%. b) Ping the server 600 times and average out the latencies in order to make sure the average is below 30 ± 0.1 ms, with a confidence interval of 95%. a) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.

NFC Tag	**NFC Tag**
1. Must be able to store and convey part serial number and QA check results.	
a) Have 1KB of storage space	a) Store exactly 1KB of data on the tag and use the smartphone to scan the tag again and ensure that 1KB of data has been received.
b) Ability to be accessed in the range of 4cm ±2cm's	b) Using a caliper accurate to 0.01cm, place the tag exactly 4cm's away from the smartphone and scan the tag. Repeat the procedure at a distance of 2 cm's and 6cm's to verify that smartphone can still read the tag.

v. Tolerance & Probability Analysis

The analog temperature sensor in Case Study 1 has a larger tolerance than the digital temperature sensor in Case Study 2, (±0.5 °C vs. ±0.1 °C) since the thermistor measures temperature by acting as a variable resistor which is more prone to error.

The accelerometer has much more tolerance as any measurement close to or above 1G corresponds to a likely fall or a slide. Therefore, the only critical application of the sensor is to be able to measure big changes in horizontal and vertical G's. For this sensor 10% error is acceptable.

Due to the nature of wireless communications, it is likely that some data corruption may occur during transfer. This error rate should not exceed 0.012% so that when in excess of 90 packets are sent, we can be sure that the data is being sent correctly.

For the wireless applications, the latency should be below 30 ± 1 ms. This is very critical as a number of expected accessed to the server, having larger delays up can delay the server response further, thus affecting the functioning of different applications.

vi. Ethical Issues

We agree and abide to the IEEE code of Ethics. We will follow the rules listed that applied to our project.

1. ***to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.[7]***

This code applies to our project as it has a lot to do with the parts required for the assembly of aircrafts. Thus, our project deals with the welfare of the public. We strive to to minimize the future risk of our project.

3. ***to be honest and realistic in stating claims or estimates based on available data [7]***

As stated earlier, our project has a potential effect on public welfare. Therefore stating realistic claims and data is absolutely required to our project as lives may be at stake.

6. ***to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations [7]***

The project is to explore with NFC technology and connect this technology and apply to the workspace. Thus it is our duty to obtain the correct information about the technology and deliver to the people who would be using our deliverables.

7. ***to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others [7]***

Our main goal is to satisfy our client and bring the deliverables that the client is expecting from us. Thus it is important for us to accept the criticism of technical work, and credit properly the contributions of others who help us throughout the project, so that we may improve our design and ideas and receive credit as well.

9. ***to avoid injuring others, their property, reputation, or employment by false or malicious action [7]***

Our project works involves a client; therefore we have to avoid any action that would harm the reputation of our client. Also since the deliverables of the project will be mainly used by the employees of our client, it is absolutely important that our project is risk free for employees.

IV. Cost and Schedule

i. Cost Analysis

Labor

Name	Hourly Rate	Total Hours Invested	Total = HR x Hours Invested x 2.5
Alper O. Olcay	$ 40.00	150	$ 15,000
Jinjoo Nam	$ 40.00	150	$ 15,000
Vigneshwar Karthikeyan	$ 40.00	150	$ 15,000
Total		450	**$45,000**

Parts

Parts	Quantity	Unit Cost	Part Number	Cost
Samsung Galaxy S3 Smartphone	1	$ 560.00	NXP: PN65 (NFC CHIP)	$ 560.00
Arduino Uno R3 Starter Pack	2	$ 65.00	Uno R3	$ 130.00
NFC Tags	3	$ 10.00	MiFare Classic Tag Assortment	$ 30.00
Digital Accelerometer	2	$ 5.94	Analog Devices ADXL312	$ 11.88
Digital Temperature Sensor	6	$ 7.67	Texas Ins. TMP103	$ 46.02
Heater Patch	5	$ 39.95	Tayco Wire-Wound Patch Heater	$ 199.75
Batteries	10	$ 1.29	Duracell 1292 Series	$ 12.90
RCL Components	-	$ 10.00	-	$10.00
Comparator	2	$ 0.41	Texas Ins. LM139	$ 0.82
Thermistor	4	$ 0.66	Vishay Comp. NTCLE203E3	$ 2.64
Op-Amp	4	$ 5.36	Texas Ins. LF356	$ 21.44
Arduino NFC Shield	1	$ 39.95	Adafruit PN532	$ 39.95

Arduino WIFI Shield	2	$ 84.95	Arduino DEV-11287	$ 84.95
Multicolor LED’s	10	$ 1.49	Sun LED XLMDKCBDBGA107M	$ 14.90
Total				**$ 1165.29**

Grand Total

Section	**Cost**
Labor	$ 45,000.00
Parts	$ 1165.29
Total	**$ 46,165.29**

ii. Schedule

Week	**Tasks**	**Responsibility**
4-Feb	Finalize and hand in proposal	Alper
	Determine which NFC tags are to be bought and order them	Alper
	Verify the need of additional circuit modifications	Vigneshwar
	Divide the project into case studies	Jinjoo
11-Feb	Start designing the heat treatment circuit	Jinjoo
	Design preliminary version of the sensor bundle	Alper
	Design preliminary version of the digital bridge-microcontroller interface	Vigneshwar
18-Feb	Start designing the smartphone application	Jinjoo
	Start building the back-end server	Vigneshwar
25-Feb	Finish up the design review	Alper
	Build the heat treatment circuit	Alper
	Build the sensor bundle	Vigneshwar
4-Mar	Start coding for the smartphone application	Jinjoo
11-Mar	Begin integration of app to hardware component	Jinjoo

	Integrate the sensor bundle with the microcontroller	Alper
18-Mar	Program the microcontrollers	Vigneshwar
25-Mar	Put final touches on the mock demo	Vigneshwar
	Assemble the first sensor bundle PCB	Alper
1-Apr	Request First Revision PCB	Vigneshwar
	Test the power system	Jinjoo
8-Apr	Request Final Revision PCB	Vigneshwar
	Test the heat treatment circuit	Alper
	Test the sensor bundle and microcontrollers	Vigneshwar
15-Apr	Run a test with all the components involved	Vigneshwar
	Fix remaining issues	Jinjoo
	Work on presentation and demo	Alper
	Prepare Final Paper	Alper
22-Apr	Run final tests	Vigneshwar
29-Apr	Final Presentations	Alper
	Final Papers Due	Jinjoo
	Checkout/Awards	Vigneshwar

iii. Safety Considerations

Our project makes use of multiple hardware components yet, due to power consumption issues, almost all parts function with less than 1mA, giving out a total current consumption of no more than 5mA. A DC current in this range gives the effect of a slight shock when contacted with a human body, and is generally harmless.

However, as with all electrical equipment, caution is the key. In order to prevent any harmful effects, location of all power switches and grounds should be known during the testing of the circuit.

V. References

[1] *“TEXAS INSTRUMENTS:* Low-Power, Digital Temperature Sensor with Two-Wire Interface in WCSP” DataSheet[Online]. Available: http://www.ti.com/lit/ds/symlink/tmp103.pdf

[2] *“TEXAS INSTRUMENTS:* JFET Input Operational Amplifiers” DataSheet[Online]. Available: http://www.ti.com/lit/ds/symlink/lf356.pdf

[3] *“TEXAS INSTRUMENTS:* Precision Temperature Sensors” DataSheet[Online]. Available: http://www.ti.com/lit/ds/symlink/lm335.pdf

[4] *“Boeing RFID Applications:* Confidential”

[5] *“ANALOG DEVICES:* Digital Accelerometer ADXL312” DataSheet[Online]. Available: http://www.analog.com/static/imported-files/data_sheets/ADXL312.pdf

[6] “*VISHAY:* NTC Thermistors, Radial Leaded, Accuracy Line” DataSheet[Online]. Avaliable: http://www.vishay.com/docs/29048/ntcle203.pdf

[7] *IEEE Code of Ethics*[Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html

[8] “*SunLED:* Full Color LED Lamp” DataSheet[Online]. Available: http://www.pololu.com/file/0J133/XLMDKCBDBGA107M.pdf

[9] "Wireless Reliability: Rethinking 802.11 Packet Loss." *University of Notre Dame*. David C. Salyers, Aaron Striegel, Christian Poellabauer, n.d. [Online]. Avaliable: http://www.cse.nd.edu/Reports/2007/TR-2007-06.pdf