The “Jeff” Tracker

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I. Introduction

As any engineer can attest, modern technology has grown to a degree that is far greater than any known before. The proof of this statement can be seen by how much easier certain aspects of our lives have improved thanks to the technology we have available today, such as cars and planes for transportation, and telephones for communication. Of course, since society is still growing, it is the job of the engineer to continue to improve aspects of life to help society grow without repercussions or problems. One way that I, as a new engineer, seek to help society is by creating a method to help alleviate a problem that can happen to anyone at any time; trying to find certain objects or people in a particular area at any given time. This is done through the use of a commonly utilized technology known as RFIDs (Radio Frequency Identification Devices), due to its easy application at certain close ranges.

While creating a tracking system of such a scale is tricky, it is possible through RFIDs readers and tags, as well as minimalizing the scale at which the system will be first applied, while at the same time making expanding the system possible. The final project will allow any user to see where a tracked object or person is based on proximity to an active reader unit, without having to worry about lack of response from the locating tag. Of course, for the sake of this project, it is important to note that the focus of this project shall be within a confined building, as the technology utilized in this project have difficulties in operating in open areas. That being said, it would be possible to utilize such a system in a larger area, provided that there are enough RFID readers to detect the tags, as well as the wiring necessary to connect all the readers together to the microprocessor that helps them operate at once. Overall, whether it be for the purpose of tracking a particular person or an important object, RFIDs are certainly an asset when it comes to ease of tracking.
II. Background

The first thing that should be addressed in this project is the following question; what is an RFID? As noted before, RFID stands for Radio Frequency Identification Device, and they can have multiple purposes. Their most common purpose is to allow for the tracking of certain objects or people in a confined space, with the best example of this being the plastic tags commonly found on clothing and electronics in stores, as well as the readers that are positioned near the exits of said stores that can detect stolen merchandise through the tags present on them. As for how they operate, the utilization of radio frequencies allows for communication between both the tags and the readers without the need for a physical medium, such as a wire or coaxial cable.

Of course, it is important to note that there are a wide variety of radio frequencies that can be utilized in an RFID system, with the size of the frequency determining how close the tag and reader have to be to allow for communication. For example, a system operating at 135 kHz will only work if both the tag and the reader are practically next to each other to the point of touching, while a system operating at 915 MHz can allow for the reader to identify a tag from a distance of up to 1 meter away [1]. Based on this information, the system was created to operate in the UHF (Ultra High Frequency) range to allow for communication between both the tag and the reader at an acceptable distance, with the frequency of 915 MHz being chosen due to it being the legal operating frequency for RFID systems in said range. Of course, one could argue that the best way to track someone would be through GPS (global positioning system), or even that the Wi-Fi system of a building can serve as the best way to track a wireless tag, but there are problems with both ideas that prevent their use for this project. For the GPS idea, there are times where, due to the composition of certain buildings, that the signal cannot be read, as well as the
fact that GPS signals do not allow a user to know which floor the tag is on if the building it is in has multiple floors. As for Wi-Fi, there are certain points inside Wi-Fi available buildings that lack the proper signal to allow for wireless communication. With these factors in mind, creating a system that operates through RFIDs was the best way to allow for the most accurate form of tracking available.

Based on the facts about RFIDs, it was decided that this project would have the following design goals:

- The system should be able to have separate RFID readers that connect to the same microprocessor.
- An RFID reader should be able to notify the microprocessor whenever it detects an RFID tag.
- The microprocessor should show when a specific reader detects an RFID tag.

The idea behind these goals was that multiple readers would be created and then placed inside a building.

III. Project Design

The focus of this project was to create an RFID system that would allow one to track a certain person or object within a certain area, with said area being determined by the placement of separate RFID readers that were all connected to a single microprocessor. While it would be possible to design both an RFID tag and reader, focus was diverted towards creating an RFID reader, while the tags, due to the complexity of their design and the limited resource-based purposes, were purchased separately for use later. While the RFID tags were capable of self-operation once they receive a signal in the proper frequency, there was work to do so that the
readers were capable of detecting said tags through the broadcasting and detection of the proper frequencies.

A. Hardware Design

The hardware design for the RFID reader was divided into two key sections; the transmitter and the receiver, with the transmitter allowing the reader to broadcast at the proper frequency, while the receiver would pick up the signal emitted from a responding RFID tag, like the ones shown in Figure 1, and process it in a way that would allow a microprocessor to interpret it.

![Figure 1: 915 MHz RFID tags](image)

For the transmitter, it was important to choose a transmission component that was capable of broadcasting a frequency of 915 MHz while being compatible with the STM32F407VG microprocessor that was used to operate the readers built. Eventually, the SI4021 transmitter, as shown in Figure 2, was chosen due to its ability to broadcast at said frequency while also being able to operate on a 5V power source, like the microprocessor [2].

![Figure 2: SI4021 Transmitter](image)

Breakout boards were also utilized in this project, as the SI4021 was of the 16-TSSOP composition, necessitating their use to allow for test circuits to be constructed on a breadboard.
As for the receiver portion of the reader, a simpler circuit, as shown in Figure 3, was utilized to allow for the reception and the interpretation of the signal without interfering with the transmitter portion of the reader [3].

Figure 3: Circuit Design for RFID Receiver

In the final schematic, as shown in Figure 4, both the transmitter and the receiver were to be placed on the final PCB board. Not only would this minimalize the costs in PCB board production, but it would also allow both the transmitter and the receiver to receive power from the same power source.

Figure 4: Final Schematic for RFID Reader

Of course, there was also of the matter of providing both the transmitter and receiver a means by which to allow them to send and receive radio signals respectively. Since radio frequency
antennae do not have to be overly complicated to allow for this project to function, some copper wiring was used and cut to appropriate length of about 78 mm [4]. Once completed, the overall design for the reader would allow for wireless communication with the RFID tags, as shown in Figure 5, allowing a user to determine whether an RFID tag is located near the reader used in this project.

![Figure 5: Block Diagram of Hardware Design](image)

**B. Software Design**

The focus of the software design was also twofold; it had to both send the proper commands to the transmitter so that it would broadcast at the right frequency and respond properly to any signal received from the RFID reader. The commands for the transmitter were sent over through the SPI (Serial Port Interface) communication function on the microprocessor. The reason why SPI communication was necessary was because the SI4021 transmitter could receive commands using such a method, as well as the fact that it minimalized the amount of wires needed to connect the two components together. As for the reception part of the program, it was a simple matter of checking the port connected to receiving circuit to see whether an RFID tag sent a response signal to the reader. With both parts working together, as shown in Figure 6, the reader is capable of both sending and receiving signals to scan for nearby RFID tags.
The main structure of the software is also displayed in the following representation of the code:

Enable the Clocks for GPIO ports A, C, D, and E

Set up Port A 5-7 to enable SPI communication

Set Port C and E to general output mode

Set Port E7 to high

Set Port D to general input mode

Configure SPI mode to set to master mode, one-way transmission, and 8-bit mode

Transmit commands via 8-bit lines by toggling output at E7 (set low at start of transmission and high at end)

While(1)

{If Port D1 is set to high, set output at C1 to high
Set C1 to low otherwise}

**IV. Results**

At the writing of this paper, the resulting RFID reader, shown in Figure 7, can do the following:
• The system can transmit a 915 MHz signal to an RFID tag.

While the transmission part of the reader is working, it is unknown if the receiver portion of the reader is functioning due to an unknown error.

• The system is capable of expansion through the addition of more RFID reader.

This based on how the microprocessor is to send the same command sequence to the transmitter on each reader, meaning that the only necessary change to the software needed is to add a different input and output that is relative to the receiver of the added reader.

Figure 7: Current RFID Reader

Of course, in spite of the difficulties in achieving these results, safety and costs were carefully regulated to make sure that this project was both nonhazardous and inexpensive.

A. Safety

When it comes to safely testing and operating this project, it is important to note that both the frequencies and components being used posed little threat to a person’s while the reader is on. Also, the 915 MHz frequency was chosen because of how common it is used to broadcast to RFID tags in the UHF range, as well as it being an unlicensed frequency, making it free to use without interference according to the U.S. Frequency Allocation Chart [5]. Of course, it should
also be noted that tags that were purchased are removable, allowing a user to tag someone without violating their privacy, as stated in the guidelines of the IEEE Code of Ethics [6].

B. Costs

While this project should not be considered a cheap endeavor, the overall results were not as expensive as it was previously believed. As shown in Table 1, it was initially assumed that the components necessary for this project, would be more expensive, but this was proven to be a hasty assumption, as the transmitters that were purchased proved to be both efficient and inexpensive. As for the PCB layout, the pricing of the boards was also proven to be an overestimation of the actual price, allowing the project to become an overall less expensive experience. Of course, it should be noted that the 16-TSSOP Breakout Board was not originally budgeted, but was purchased later on to aid in the testing of the SI4021 Transmitters. The 10 MHz was also not originally budgeted, but it was purchased later into the project since the SI4021 transmitter required the crystal in order to function properly.

<table>
<thead>
<tr>
<th>Components</th>
<th>Estimated Costs</th>
<th>Actual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID Tags (915 MHz)</td>
<td>$60</td>
<td>$73.45</td>
</tr>
<tr>
<td>PCB Layout</td>
<td>$200</td>
<td>$127</td>
</tr>
<tr>
<td>RF Transmitters</td>
<td>$50</td>
<td>$11.94</td>
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<tr>
<td>16-TSSOP Breakout Board</td>
<td></td>
<td>$3.95</td>
</tr>
<tr>
<td>10 MHz Crystal</td>
<td></td>
<td>$7.11</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td><strong>$310</strong></td>
<td><strong>$225.45</strong></td>
</tr>
</tbody>
</table>

V. Conclusion and Recommendations

Overall, this project has proven to be a learning experience into how RFID technology functions, as well as how a tracking system comes together through wireless communication
between key components. Of course, like any other project, this one has the potential to be improved upon through various means. One such method of improvement would be through the readers themselves, as while the components that were used in their construction were both cheap and reliable, it is possible to utilize other components to improve performance. Another such improvement would be the addition of an RF coupler, which would allow for one antenna to be capable of both the transmission and reception of radio frequencies. The best way to improve on such a project, though, would be through the overall improvement of RFID technology, which would allow for more widespread applications to be possible for such a system. Of course, said improvement is more likely to come an improved understanding of how radio frequencies function, as well as how they can be used with today’s technology, especially since the need to track certain things at certain times is a need that crops up from time to time. Overall, as the need for new technology to aid in such efforts grows, the technology associated will grow as well.
VI. Appendices

Software Code:
/*Senior Project  March 30, 2018           Aaron Wagmeister
*/
#include "stm32f407vg.h"
#include "stm32f4xx.h"                 // Device header

void GPIOConfig(void);
void SPI_Con(void);
uint8_t data;

void SPI1_send(uint8_t data)
{
    SPI1_DR = data;
    while( (SPI1_SR > 0x80) ); // wait until transmit complete
}

void Setting (void); //Setting command to Xmitr

int main()
{
    GPIOConfig();
    SPI_Con();
    GPIOC_ODR |= 0;

    // /* Initialize SPI */
    // /* SCK = PA5, MOSI = PA7, MISO = PA6 */
    // TM_SPI_Init(SPI1, TM_SPI_PinsPack_1);
    //
    // /* Send 0x15 over SPI1 */
    // TM_SPI_Send(SPI1, 0x15);
   //GPIOE->BSRRH |= GPIO_Pin_7;
    GPIOE_ODR &= 0x00;  // set PE7 (CS) low
    SPI1_send(0x98);  // transmit Setting data
    SPI1_send(0x80);
    GPIOE_ODR |= 0x80; // set PE7 (CS) high
    GPIOE_ODR &= 0x00;  // set PE7 (CS) low
    SPI1_send(0xC0);  // transmit Power data
SPI1_send(0x00);
GPIOE_ODR |= 0x80; // set PE7 (CS) high

GPIOE_ODR &= 0x00; // set PE7 (CS) low
SPI1_send(0xC4); // transmit Sleep data
SPI1_send(0x02);
GPIOE_ODR |= 0x80; // set PE7 (CS) high

while(1)
{
    if(GPIOD_IDR != 0x0)
        GPIOC_ODR |= 0x1;
    else
        GPIOC_ODR &= 0x0;
}

void GPIOConfig(void)
{
    //GPIO_InitTypeDef GPIO_InitStruct;

    // enable clock for A5-7, C and D
    RCC_AHB1ENR |= 0xD;

    /* configure pins used by SPI1
    * PA5 = SCK
    * PA6 = MISO
    * PA7 = MOSI
    */
    //GPIO_InitStruct.GPIO_Pin = GPIO_Pin_7 | GPIO_Pin_6 | GPIO_Pin_5;
    GPIOA_MODER |= 0xA800; //A5-7 Alt function
    GPIOA_OTYPER |= 0x0000; //set alt function
    GPIOA_OSPEEDER |= 0xFC00; //Set to very high speed
    GPIOA_PUPDR &= 0x0000; //no pull

    // connect SPI1 pins to SPI alternate function
    GPIOA_AFRL |= 0x55500000;
GPIOC_MODER |= 0x5; //General output for display, D is input by default

// enable clock for used IO pins
RCC_AHB1ENR |= 0x10;

/* Configure PE7 */
GPIOE_MODER |= 0x4000; //E7 output
GPIOE_OTYPER |= 0x0000; //set pull up-pull down
GPIOE_OSPEEDER |= 0xC000; //set to very high speed
GPIOE_PUPDR |= 0x4000; //pull up

GPIOE_ODR |= 0x80; // set PE7 high
}

void SPI_Con(void)
{
    //SPI_InitTypeDef SPI_InitStruct;

    // enable peripheral clock
    RCC_APB2ENR |= 0x1000;

    SPI1_CR1 |= 0x40; //enable SPI
    SPI1_CR1 |= 0x4; //transmit in master mode
    SPI1_CR1 |= 0x0; // clock is low when idle, data sampled at first edge
    SPI1_CR1 |= 0x8; //baud rate control
    SPI1_CR1 |= 0x00; // data is transmitted MSB first
    SPI1_CR1 |= 0x4000; //Transmit only
    SPI1_CR1 |= 0x000; //8 bit data transfer rate
}
VII. Reference


