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Simulating a Positioning System

RFID and Hall Effect Simulation

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Abstract

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KONE Corporation wants to improve the testing environment of one of their products to make it more similar to a real elevator. The company is currently using two different kinds of testing environments for the product. One has a completely simulated board in use and in the other environment the whole physical implementation of the environment causes problems in certain situations. As a result, the aim of the research project described in this thesis was to explore the new opportunities for these test systems.

The research project consisted of simulating two different interfaces for the object board: the Hall effect and Radio Frequency Identification. The basics of the Hall effect and simulation possibilities were studied on a theoretical level. Based on the theory the best and the most cost-effective way of simulating Hall voltage proved to be Digital-to-Analog converters.

A few different ways were used to simulate Radio Frequency Identification. In addition other possibilities to simulate this interface were investigated in theory. In detail the project focused on simulating RFID transceivers with a microcontroller.

With the help of this research project, working simulation possibilities for both interfaces of the object boards could be found.

In conclusion the thesis shows that KONE Corporation can improve the testing environment of certain products so that all the components of the elevator system can be used in the environment without that physical size of the environment being a problem in the future.

Keywords	RFID, Hall effect, Hall voltage

Tiivistelmä

Tekijä Otsikko Sivumäärä Aika	Matti Leino Paikannusjärjestelmän simulointi 26 sivua 06.05.2014
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KONE Oyj halusi kehittää erään tuotteensa testausjärjestelmää vastaamaan enemmän oikean hissin tilannetta. Yrityksellä on tällä hetkellä käytössä kaksi eri testausjärjestelmää kyseistä tuotetta varten, joista toisessa on simuloitu testausjärjestelmän osaa täysin ja toisessa testausjärjestelmän fyysinen toteutus aiheuttaa ongelmia tulevaisuudessa. Insinöörityön tavoitteena oli tutkia uusia mahdollisuuksia toteuttaa nämä testausjärjestelmät.

Tutkimusprojekti koostui erään tuotteen paikannusjärjestelmän Hall-ilmiön sekä radiotaajuustunnistautumisen simuloimisesta testausjärjestelmälle.

Hall-ilmiön perusteita ja simulointimahdollisuuksia tutkittiin teoriatasolla. Teorian perusteella parhaimmaksi ja kustannustehokkaimmaksi simulointitavaksi osoittautui DA-muuntimien käyttäminen Hall-jännitteen simulointiin.

Radiotaajuustunnistautumista yritettiin projektissa simuloida muutamalla eri tavalla sekä teorian tasolla tutkittiin myös muita mahdollisuuksia. Projektissa keskityttiin erityisesti simuloimaan RFID-lähetin-vastaanotinpiiriä mikrokontrollerilla.

Tutkimusprojektin avulla pystyttiin löytämään kohdekortin molemmille rajapinnoille toimivia simulointimahdollisuuksia.

Opinnäytetyö osoittaa, että KONE Oyj voi kehittää erään tuotteensa testausjärjestelmää niin että siinä voidaan käyttää hissijärjestelmän kaikkia osia ilman että testausjärjestelmän fyysinen koko tulisi esteeksi tulevaisuudessa.

Avainsanat	Radiotaajuinen etätunnistus, Hall-ilmiö, Hall-jännite

Contents

Abbreviations

ADC	Analog to Digital Converter
AIC	Advanced Interrupt Controller
DAC	Digital to Analog Converter
DBGU	Debug Unit
DMA	Direct Memory Access
FIFO	First In, First Out
HF	High Frequency
ISO	International Organization for Standardization
KONE	KONE Oyj
LF	Low Frequency
PCB	Printed Circuit Board
PDC	Peripheral DMA Controller
PIO	Programmed Input/Output
RFID	Radio Frequency Identification
RISC	Reduced Instruction Set Computing
R&D	Research and Development
SPI	Serial Peripheral Interface
TI	Texas Instruments
TTS	KONE Time Triggered Safety Protocol
UID	Unique Identification Number

1 Introduction

This thesis describes different kinds of methods for simulating Radio Frequency Identification (RFID) tags and Hall effect in a real life simulator environment. The thesis mostly focuses on RFID but the Hall effect was also under deep investigation in the project described in this thesis.

1.1 Structure of the Thesis

The thesis begins with a theoretical section of RFID and Hall effect in chapter 2. The chapter explains briefly the basics of RFID and Hall effect so it is easier to understand the rest of the thesis.

The thesis continues with simulation board electrification in chapter 3. This chapter explains what is needed from the electrification for being able to simulate the two needed interfaces in this project. Subsequently a couple of examples are given about how to create the electrification for both the Hall effect simulation and RFID simulation.

Chapter 4 explains how radio frequency identification is used in the object board. The chapter also shows a couple of ways of how RFID Unique Identification Numbers (UID) were simulated in this project and what method was found most appropriate for this project and how that kind of situation could be implemented.

Chapter 5 is a theoretical section about the Hall effect simulation. The chapter explains how the Hall effect is used in the object system and how to simulate the Hall effect in the future.

Chapter 6 summarises the results of this investigation project. Is this kind of simulation board feasible? What situations are needed to be considered before starting to implement this? What could already be implemented? How should everything be done in the future?

In conclusion, future research ideas and development possibilities are considered.

1.2 Scope of the Work

When reading this thesis it is good to remember that the project described here was only an investigation project about the subject. What does this mean then? The client who was KONE Oyj wanted someone to investigate whether this kind of testing environment update is feasible before they start implementing it by themselves.

2 What are RFID and Hall effect?

2.1 Radio-Frequency Identification (RFID)

Radio-frequency identification is a term for contactless transfer of data via radio-frequency electromagnetic fields. The reader communicates in a certain radio-frequency bandwidth with a tag that contains some information. This kind of communication is used for example to track goods in a warehouse. [1; 2]

RFID tags can be passive or active. Passive tags do not contain any power supply of their own. They get their power for communication from an inductive coupling between the reader antenna and tag antenna; this is for LF and HF frequencies. Active tags have their own power supply, but they are not described in this thesis and neither are UHF and microwave frequencies which use real antennas. [1; 2]

‘Antenna’ is a somewhat misleading word for an LF and HF frequencies because the reader and tag do not transmit radio waves for each other; they communicate by modulating an oscillating magnetic field. The reader creates an oscillating magnetic field by conducting alternating current (AC) to its antenna loop. This magnetic field induces similar AC to the tag’s coil. The chip that the tag has gets its power from inductive current and the data in the EEPROM memory of the chip is used for modulating the current of the coil. It is then visible, over the magnetic field, in the reader’s antenna loop voltage. [1]

There are set standards and regulations related to RFID by different organizations, for example the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). LF (125–134.2 kHz and 140–148.5 kHz) tags and HF (13.56 MHz) tags can be used globally without a license, and other kinds of tags too, because there is no single global standard. The object system described in this thesis operates in HF 13.56 MHz and its standard is ISO/IEC 15693 [1]. RFID principles are shown in figure 1.

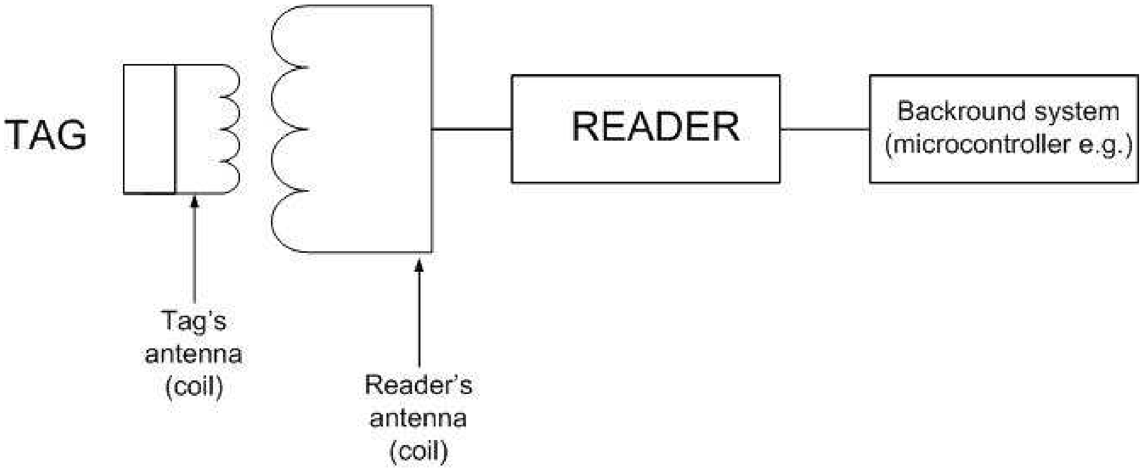

Figure 1: Rfid Principles [1]

2.2 Hall Effect

When an electrical conductor moves perpendicularly to a magnetic field, it generates a force that changes the order of charge carriers in the conductor. Positive particles move linearly to the same direction as the electric field and negative particles to the opposite direction. This force is called the Lorentz force. Due to this new order, a voltage difference is also generated across the electrical conductor. This voltage is called the Hall voltage (see Figure 2). [3; 4; 5]

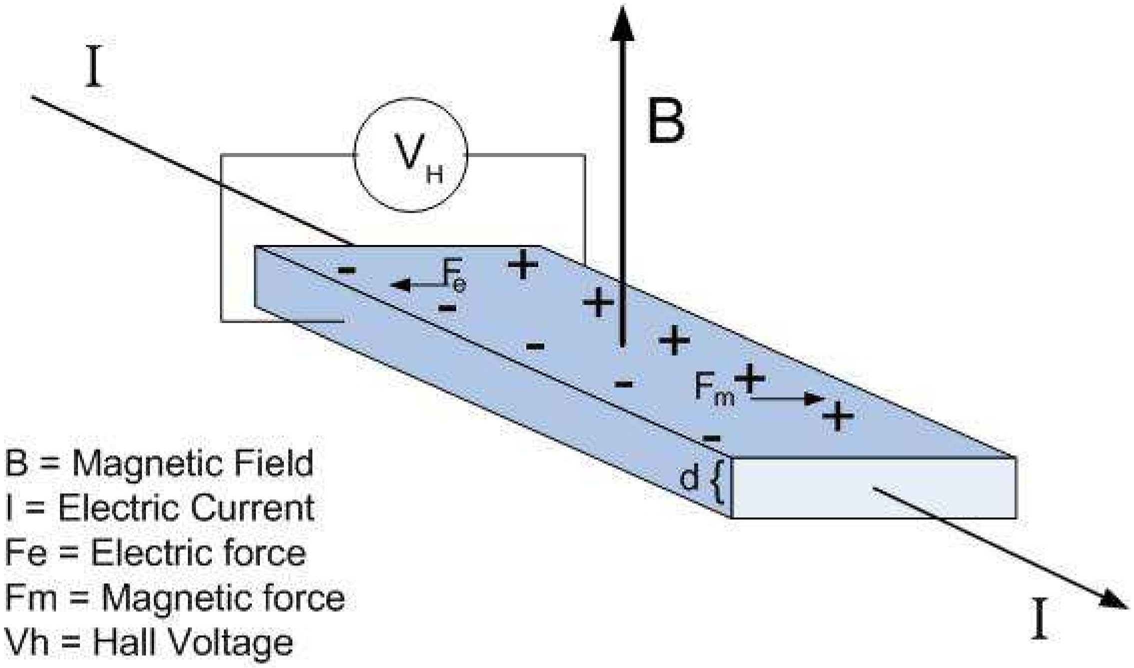

Figure 2: Hall Effect [5]

2.2.1 Physical Equations of Hall Effect and Hall Voltage

It was mentioned earlier that the Lorenz force is the main phenomena behind the Hall effect. This chapter focuses on the physical equations of the Hall effect.

Lorenz force law: [4]

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

Where q is the electrical charge of the carrier, E is the electric field, v is the velocity of the charge carrier and B is the vector representing the magnetic field. The Lorenz force can be divided into electric force and for magnetic force:

$$\overrightarrow{F_e} = q\vec{E}$$
$$\overrightarrow{F_m} = q\vec{v} \times \vec{B}$$

The electric force is straightforward, being in the direction of the electric field if charge q is positive. The magnetic force direction is obtained from the right hand rule (see Figure 3):

1. The thumb illustrates the magnetic force direction
2. The index finger illustrates the magnetic field direction
3. The middle finger illustrates the velocity of the moving direction of the positive charge carriers [3; 4; 5; 6; 10]

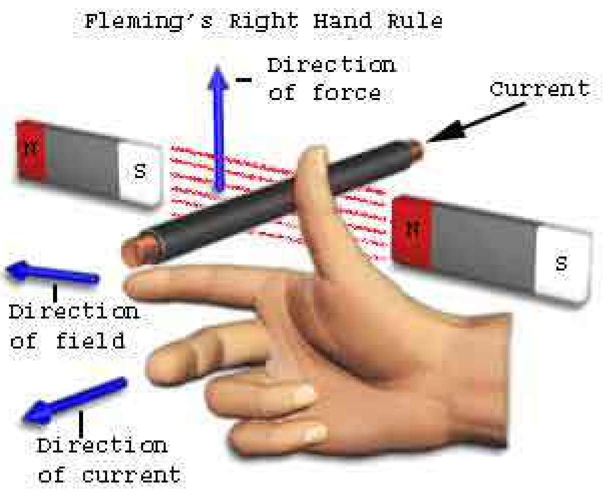

Figure 3: Right hand rule [6]

For the wire applications the magnetic force can be defined as follows:

$$\overrightarrow{F_m} = \vec{I}L \times \vec{B}$$

Where I is the electric current, L the wire's length and B the magnetic field.

The Hall voltage is given by equations:

$$F_m = ev_dB$$
$$I = neAv_d$$

Where n is the density of charge carriers, e is elementary charge, A is the area of the electrical conductor (w times d, which is the thickness of the electrical conductor in this case) and v_d is the drift velocity of the charge.

$$F_{m=\frac{eIB}{neA}}$$

At equilibrium:

$$F_m = F_e = \frac{V_h e}{w}$$

where w is the width of the electrical conductor.

And substitution gives the Hall voltage which can be defined as

$$V_h = \frac{IB}{ned}$$

Therefore, the Hall voltage is generated when an electrical conductor affects the magnetic field. [3; 5; 10]

3 Simulation Board Electrification

3.1 Prerequisites

The client set a couple of prerequisites concerning the simulation board electrification. There were also other prerequisites that were caused by the RFID simulation and the Hall effect simulation.

3.1.1 Employer Prerequisites

There were two prerequisites that were very important for the employer. The first one was the processor type and family that would be needed to use for the project, and the second one was the interface for giving the commands for this simulation board as to regarding how and when to simulate and what.

KONE have several years' experience in ARM microcontrollers, and the microcontrollers meet the needs of KONE's products. Thus it was very clear for the employer to suggest using a certain ARM microcontroller in this investigation project. The microcontroller that was chosen was a 32-bit ARM7TDMI RISC processor [8]. It was chosen because KONE had Atmel's AT91SAM7S256 development boards so there was no need to order anything new and KONE have used these development boards also in other investigation projects. [12; 14]

KONE already have one board that is simulating the same interfaces that were investigated again. However, the board also includes the object board, so environments that have this board have a somewhat different configuration compared to a real life situation. Hence, the idea was to combine the original simulation board and the new board. The original board has a TTS interface but with small changes it can be modified to have a Serial Peripheral Interface (SPI). In other words, there was also a need to somehow combine SPI for the simulation board. The object board is the board that is needed to simulate the car movement in the elevator shaft and the board is used in real elevator systems. Thus, it is the board that reads and calculates the car position in an elevator shaft via RFID and magnet interfaces. There is a block diagram in figure 4.

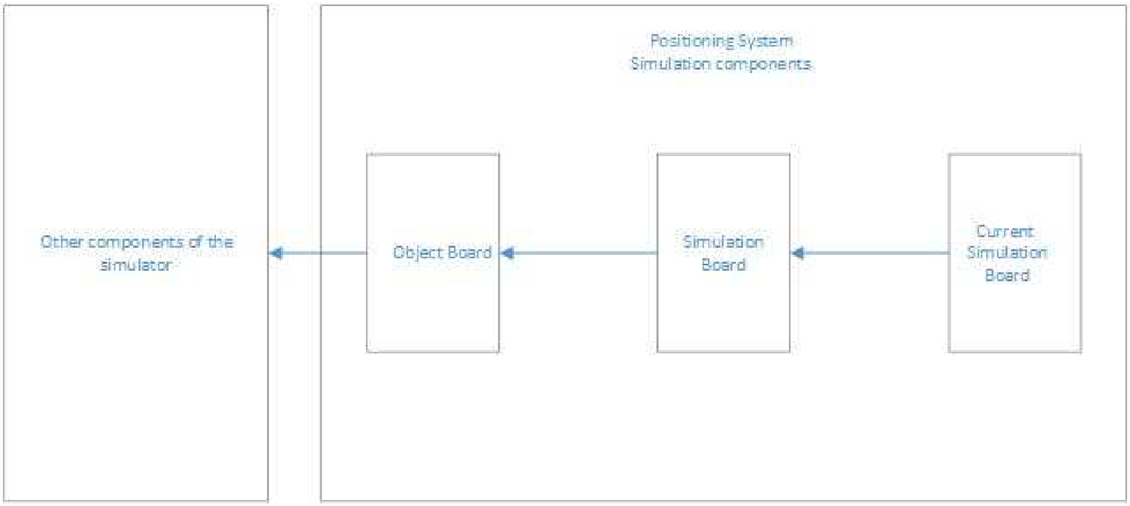

Figure 4: Simulator System Block Diagram

3.1.2 Other Prerequisites

In brief, the Hall effect refers to the voltage difference that happens when a magnet moves across an electrical conductor. Hence, basically for the voltage simulation was needed to use some voltage simulation methods such as a Digital-to-Analog Converter (DAC) or voltage generator. Voltage generators are very expensive so they were out of the question. Some processors have a DAC integrated into the microcontroller and the external ones are also pretty cheap compared to voltage generators.

RFID simulation also sets prerequisites for the board. When designing the simulation board it is necessary to think very carefully about how to handle the simulation interface of RFID in the object board. There are a couple of methods for this, and they are presented later in this document.

3.2 Hall Effect Simulation

Designing the Hall effect simulation was actually pretty easy so in this project nothing concrete was built related to the Hall effect simulation electrification. However, this was also under deep investigation.

3.2.1 Digital-to-Analog Converter

DACs are probably the easiest way to produce DC voltage so that is why they were chosen for investigation. The development board was chosen only for investigating the

RFID simulation. However, if the same microcontroller unit as in AT91SAM7S256 was used to simulate the Hall effect, there would be a need to use external DACs. KONE set a prerequisite for using certain ARM products and they did not contain DACs at all or there was only some DAC blocks integrated into them. Thus in both situations there was a need to use external DACs anyway.

When choosing DACs it is important to think about the interface that would be used for controlling them. Possible interfaces were SPI, I2C and SSC. SPI did not come to question because SPI was meant to be used for other purposes too. SPI could be used to control DACs but then there was a need to choose the main processors so that they would include enough SPI peripherals. Other workers at KONE mentioned that SSC is pretty hard to use and maybe not such a good interface for controlling DACs. Thus, the plan was to use I2C controlled DACs or SPI even though there could be some problems in finding enough SPI peripherals included in a microcontroller.

External DACs were easy to find for example from several electronic suppliers.

3.3 RFID Simulation

From the very beginning of this project it was clear that simulating RFID will definitely be the most difficult part of this project. Several meetings were arranged with KONE R&D experts which dealt with the methods that could be tried and what methods would work. There was also an e-mail exchange going on all the time with an expert from Texas Instruments Analog Field Applications. Texas Instruments was contacted because the object board is using an RFID receiver of Texas Instruments. There was a discussion about the possibilities to use programmable RFID tags in this project and also whether the same receiver could be used for simulating the RFID tag.

3.3.1 Homemade RFID Tag Emulator

When considering the different techniques for simulating RFID tags with different UIDs for the object board, the first idea that came up was that it would be very remarkable if there was a homemade emulator that acted like a real tag and UIDs which could change in real time. Definitely this would be the hardest way to simulate an RFID tag but it would be very unique.

Theoretically the emulator would only need an antenna that operates in the same frequency as the object board's RFID reader antenna and a micro controller that has a program which emulates the tag. [7]

However, this situation was not so simple because the UIDs needed to change in real time. Thus, this had to be thought of more with one of the KONE experts. Finally a couple of useful ideas were discovered.

As explained in chapter 2, an RFID tag is basically an LC circuit which communicates back to the reader by modulating its own inductance. The first idea was to have the object board without modification and then the simulation board would have an LC circuit and a microcontroller that short circuits the coil with a transistor through a resistor. First, the antenna circuit from the RFID tags that were used in this project was tested, but it was too hard to remove the IC from the tag because it was so little. Hence a few calculations were made for the antenna and then the board was built, and whether it could be used for simulating an RFID tag was tested. The simulation board electrification is a modified version of the behaviour of a real tag. The data that a real tag has modulates the carrier wave back to the reader, but in this case the modulation was done by short circuiting the coil with a microcontroller.

After this there was also a new idea that the simulation board would not necessarily need its own antenna for the simulation board. The simulation board could also use the reader's antenna with the same method. This was not tried at all because a prerequisite was that it would be best if there was no need to make any changes to the object board. There was also an issue with the configuration: if the reader's coil was short circuited, it would lower the amplitude of the signal, making the situation completely different from a situation with a real tag. In this case radio waves were modulated already in the object board's antenna.

Both of these ideas were disregarded because this would be too fancy for the first implementation and would take too many resources at this point.

3.3.2 What Texas Instruments Could Provide

Texas Instruments were contacted and asked whether they have a demo tag the UID of which could be changed. The answer from Texas Instruments was that they do not have one but there could also be other problems with this kind of programmable tag. For example, the programming of a new UID could take too much time for this kind of environment. Thus this idea was disregarded.

There was also discussion with the Texas Instruments contact person whether the same transceiver chip that is used in the object board could be used for simulating the tag. The contact person was not sure whether it could be used but he was willing to help if this kind of new way of using their products is done in the future. This is something that would really need to be thought of in the future because then there could be two of these object boards in the simulator, one for simulating RFID tags and the other one for reading those.

3.3.3 Simulating Texas Instruments Reader with a Microcontroller

When it was noticed that the homemade RFID tag emulator would be pretty hard to create and also when Texas Instruments did not have anything ready to offer that is a complete solution, the object board and especially its hardware design were taken under more specific review.

As it was earlier mentioned, the object board uses Texas Instruments' RFID transceiver that communicates in 13.56 MHz frequency. The reader can communicate with the microcontroller with either a parallel 8-pin interface and the clock signal or an SPI. In this situation the object board and the reader communicated with the SPI. The object board block diagram is shown in figure 7.

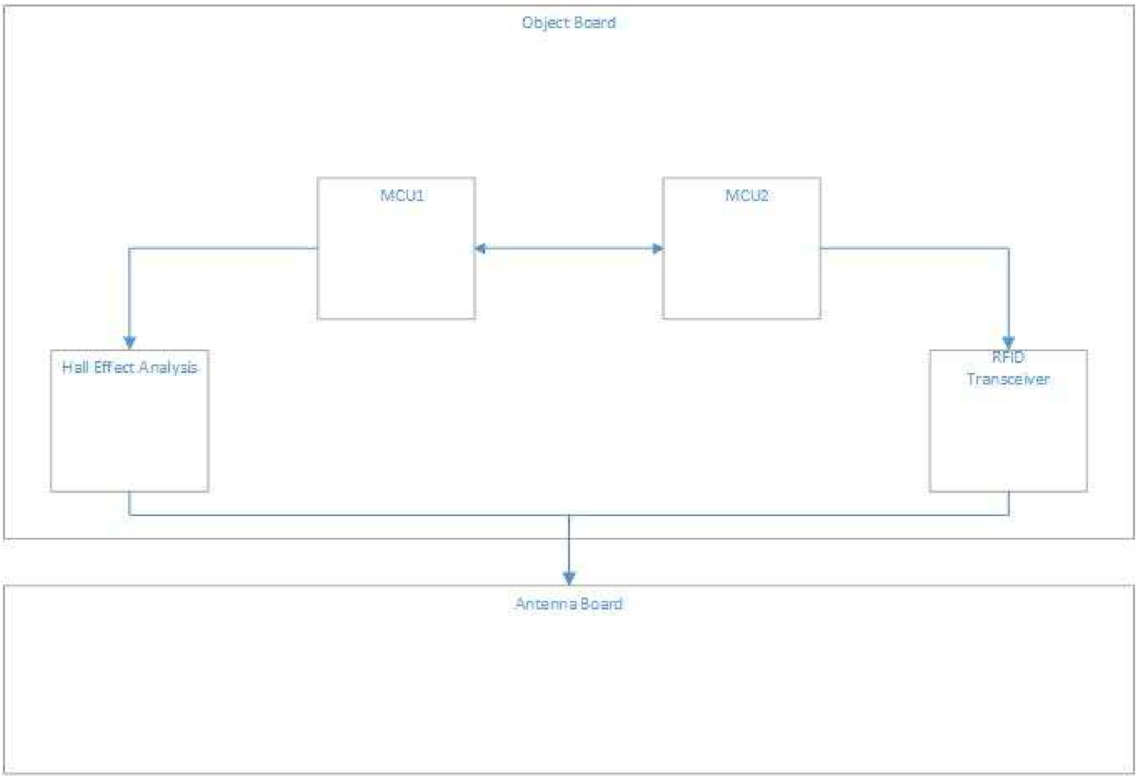

Figure 5: Object board block diagram

The SPI is a 4-wire simple serial communications interface that allows microprocessors/microcontrollers to communicate with peripheral devices such as ADCs and DACs. The SPI was developed primarily for communication between the host processor and peripherals but communication between two processors/microcontrollers is also possible. The SPI bus is usually used on the printed circuit board (PCB) because using it outside the PCB area could cause problems for the communication. “The SPI Bus was designed to transfer data between various IC chips, at very high speeds. Due to this high-speed aspect, the bus lines cannot be too long, because their reactance increases too much, and the Bus becomes unusable. However, it is possible to use the SPI Bus outside the PCB at low speeds, but this is not quite practical.” [11]

An SPI protocol specifies four signal wires (see Figure 8):

1. Master Out Slave In (MOSI) – The MOSI signal is generated by the master, the recipient is the slave.
2. Master In Slave Out (MISO) – The slaves generate MISO signals and the recipient is the master.

3 Serial Clock (SCLK or SCK) – An SCLK signal is generated by the master to synchronize data transfers between the master and the slave.

4 Slave Select (SS) from master to Chip Select (CS) of slave – The SS signal is generated by the master to select individual slave/peripheral devices. The SS/CS is an active low signal. [11]

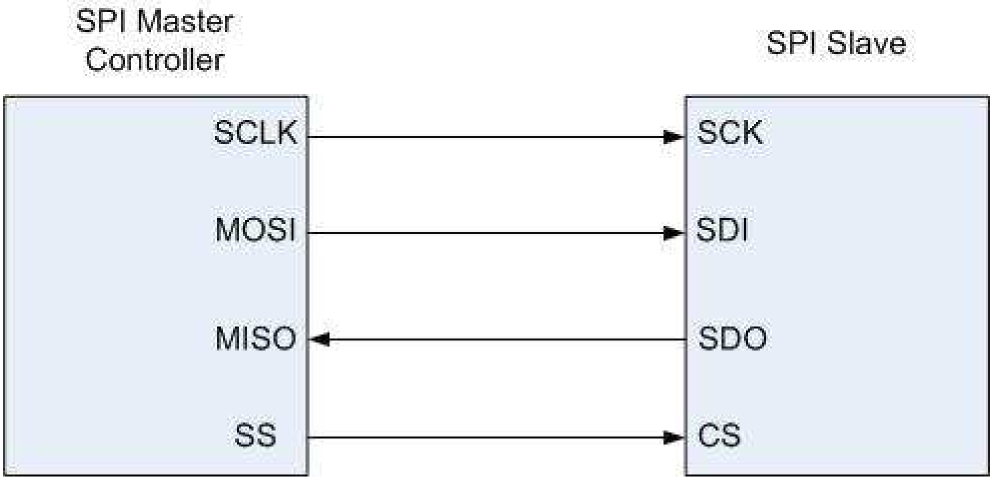

Figure 6: SPI Single Master - Single Slave configuration [11]

MOSI and MISO could be called data lines. The data moves between the master and slave on these lines. Furthermore SCLK and SS are the control lines in the SPI interface that makes the correct timings between the master and slave or with multiple slaves.

Communication between master and slave:

The communication is always initiated by the master. It first sets the clock signal to use the frequency that the slave device supports. After this the master selects the slave by setting the SS to a “low” state. Then there might be some waiting before the data transfer can be started but this depends on the operation of the slave device. After these steps the master can write information to MOSI and also read the MISO line.

SPI supports full-duplex data transmission. As an online course on embedded systems teaches, “That means the master sends a bit on the MOSI line; the slave reads it from that same line and the slave sends a bit on the MISO line; the master reads it from that same line.” [11]

Clock polarity and phase:

When the master sets the clock frequency it must also define the clock polarity (CPOL) and clock phase (CPHA) with respect to the data. There are four possible modes that can be used in the SPI protocol (see Table 1):

SPI MODE	CPOL	CPHA
0	0	0
1	0	1
2	1	0
3	1	1

Table 1: SPI Clock Polarity and Phase

”If the phase of the clock is zero (i.e. CPHA = 0) data is latched at the rising edge of the clock with CPOL = 0, and at the falling edge of the clock with CPOL = 1.
If CPHA = 1, the polarities are reversed. Data is latched at the falling edge of the clock with CPOL = 0, and at the rising edge with CPOL = 1.” [11]

Chapter 4 describes how the configuration was made and how it managed to simulate the transceiver.

Advantages and disadvantages:
The major benefit of using this simulating method is that there was a specification about what should be done. In addition naturally the specification was the datasheet of Texas Instruments RFID transceiver. However it is also good to remember that the other major benefit in this simulation was the configuration of the SPI because it is rather easy to do.

The major disadvantage of this method was that SPI wires had to be used outside the PCB board during the testing period. Because this project was only an investigation project with a minimum budget so nothing could be built in the PCB before it was proven to work. However, if this worked with wires that are not a part of the PCB itself, it would also then work with the PCB that has the simulation microcontroller unit and the other components from the object board. Other issues were also faced when configuring the SPI and implementing the transceiver but these are discussed later.

It is also good to mention here that the RFID antenna circuit still had to be left on the board because otherwise the object board’s software would complain about the missing antenna circuit. In future if the transceiver is replaced with another microcontroller, the antenna circuit could also be removed, but then predefined components should be connected to the antenna circuit’s pins to avoid complaints about the missing RFID antenna circuit.

3.3.4 Buying RFID Tag Emulator

After a couple of months of implementing the third idea a website was found on the internet that offers RFID tag emulators. There was no time to investigate how these work and whether these could be used in this project but definitely if someone starts to implement this kind of simulation board these emulators should be taken under investigation. [9]

4 RFID Simulation

4.1 Basic Issues

The simulation of the transceiver was done on using an ARM development board the model of which is AT91SAM7s256-ek [15]. Requirements for the development board were simple: It should contain at least one programmable SPI block and the operation frequency of the microcontroller should be fast enough for reliable communication between the object board's MCU.

AT91SAM7s256-ek has one SPI block that has programmable 8 to 16-bit data length and four external chip selects. This MCU's maximum operation frequency is 55 MHz. It also has an Advanced Interrupt Controller (AIC) which was very useful in this simulation project. [12; 14; 15]

The development environment and compiler that were used was Keil's MDK ARM development program [13]. The JTAG-ICE and also a USB were used to flash the MCU memory for downloading the software to the chip used. AT91SAM7S-ek had two RS232 ports and one of these two ports was defined as a debugging port. DBGU was used for debugging and it was also used as a user interface. The object board had its own debugging methods that were also very useful.

Before starting the simulation project itself several smaller programs were done to became familiar with development tools and the AT91SAM7s256 evaluation kit. These programs include the basic Hello World program to get the DBGU working and Programmed Input/Output (PIO) controller programs to become familiar with PIO and AIC. Also the communication between the slave device and the master device without using AIC was tried.

The library files that were used were from Keil's software installation package.

4.2 Hello World (Configuring DBGU)

The first program for AT91SAM7s256-ek was the basic Hello World program. After the first program was selected, the software printed something out from the DBGU port.

Then the program was modified a bit so it handled both reading and writing through the DBGU port.

Configuring the DBGU port and using it was very easy because all the needed functions had already been done. Keil's software package contained a couple of example projects that were very useful to become familiar with the DBGU port.

4.3 Blinky (Getting Familiar with PIO, PDC and PMC)

To get familiar with PIO and Power Management Controller (PMC) it was very necessary to get this project done, because the PMC enables the clocks for different units in the MCU. PIO would also be needed when configuring interrupts for SPI.

Keil's software package contained project called “Blinky” that was used as an example for the tests. Thus, the completed project was used and a couple of modifications were made for it.

First there was a need to configure the clock for PIO with PMC. Then a couple of leds were initialized with the PIO and they were set to blink with a certain interval. Then the program was modified so that it would check interrupts from a couple of buttons that were in the board. Furthermore depending on the button that was pressed, the program reduced or increased the frequency of how fast the leds were blinking.

4.4 Configuring SPI without Interrupts

The first thing about studying SPIs in the project, was to configure the simulation MCU to the SPI slave device and then try to read and maybe also write something to the object board’s MCU and check from the object board’s debugging unit whether the object board has received the message or not.

Configuring the SPI was pretty hard because the transceiver can handle a couple of different ways of SPI communication. First, all the configurations were made based on transceiver’s datasheet but then the software of the object board indicated that the SPI configuration on the object board was somewhat different compared to the simulation board’s configuration.

The SPI clock was configured at the start so that CPOL was 0 and NCPHA was 1. Furthermore, this also applied when the master was writing something to the slave. Subsequently, the data transfer was valid when SCLK was on the falling edge and MOSI was valid when SCLK was on the rising edge. However when the slave wanted to write something to the master, the NCPHA configuration should be changed to 0. Then the data transfer was valid when SCLK was on the rising edge and MISO was valid when SCLK was on the falling edge. This caused difficulties in the beginning. Nevertheless, this could be solved once again by reading the related documents. The problem was that the software was changing the clock phase during communication depending on whether the board was reading or writing something for the transceiver.

When the configurations were made in the right way, the slave device managed to receive data from the master. Earlier, the data could also be received but it did not make any sense because the clock phase was wrong and in a wrong place. After receiving the correct data from the master, a small recursive program was made that first configures the SPI and then waits to get correct data from the master while being in a while-loop. Furthermore when the first correct data have been received, the program goes to the next state and so on. With this kind of program the SPI communication was working with the master device. However, the RFID data could not be simulated to the master. This working communication was noticed on the object board's debugging tool.

Later on it was discovered that the master MCU and the transceiver were configured so that the transceiver sets the external IRQ signal on for the master to let the master device know that now there is a valid UID ready for reading in First In, First Out (FIFO) data buffer.

Thus, the next thing was to use the external IRQ signal in the recursive program but without success. When setting the external IRQ on the other timings, the communication failed. Hence, it was clear that the whole SPI communication should be done with interrupts to get everything done at a correct time. The major advantage of interrupts was that the next sending value could be loaded to the FIFO at the time of reading the bytes that the master had sent. Furthermore, then the loaded values moved to the master in the next clock cycle.

4.5 Configuring SPI with Interrupts

When starting to use the interrupts in SPI communication, the code was also made more modular. Thus it will be easier to understand, control and modify it in the future.

First, a function for the SPI configuration was made under the main program. Earlier the SPI was configured in the beginning at the main program. Thus, the only difference is that now the SPI configuration has its own function. Furthermore one delay function was made to the main because it was impossible to know whether there would be a need for that. Also hardware initialization (enabling clocks for different modules) was divided into its own function. After this a configuration function for the external IRQ signal was made and set to a certain pin out. Finally an initialization function for the SPI interrupt routine was made. This was made with Advanced Interrupt Controller (AIC). Also an SPI read function was made that reads the incoming messages from the master. However, it was understood very quickly that this is not needed because the data can be read directly in the interrupt handler that will be made. Furthermore, this would be a more effective way than using a random function for it.

Subsequently the interrupts were configured with AIC and the priority order was set so that SPI has the highest priority. Hence, every time the SPI interrupt comes the configured interrupt handler starts, and then the handler should read the coming SPI message and perform or start the actions that are needed. Because the possible values that the master would send were known, it was pretty easy to make a structure that handles the incoming values even though this was the first time to make any kind of an interrupt handler. In other words, a switch-case structure was made that had all the possible cases that could happen and of course the default case where the incoming data were ignored and the SPI was reconfigured to get a new start.

When the switch-case structure was ready, it was time to start to determine what should be the actions that need to be done when a certain value from the master has been received.

SPI with Interrupts Results

With the interrupt service routine, the simulation board managed to communicate with the object board processor and simulate different RFID tags. The object board had a serial debugging option and it was visible that it managed to read simulated tags. However, there were still some problems with this because the communication sometimes stopped but the tags could be simulated for a while. This was the breakthrough in the simulation process. Thus, it is pretty certain that with more investigation and with more hard work the whole RFID communication can be simulated with SPI also for a long period.

5 Hall Effect Simulation

As mentioned earlier the thesis did not focus on Hall effect simulation. However some research was made for finding possible DACs that could be used for simulating Hall voltages. One possible chip could be Texas Instruments' PCM1602A Digital-to-Analog Converter. It has a 24-bit resolution, a sampling rate of 192 kHz and six channels. For example this chip would be more than enough to simulate six Hall voltages for the object board, and using two of these, all the twelve channels could be simulated. [17]

Why then would this DAC be enough for the system and another one not? This is a complicated question but it is important to focus on the facts behind this. To begin with the real Hall voltage that is produced is sinusoidal AC voltage. When using DACs, they produce an analog voltage but depending on the sampling rate and resolution, it could differ from the real sinusoidal AC voltage. Hence, if the DACs are not fast enough to produce new voltage levels there might be aliasing in the output voltage. Thus the produced sinusoidal AC voltage is not the same as in real life and this might cause problems. Also if the sampling rate is too low, the ADCs might read the incoming values at a wrong time and then miss for example important information about the voltage, such as the peak levels. Figure 9 illustrates this in more detail.

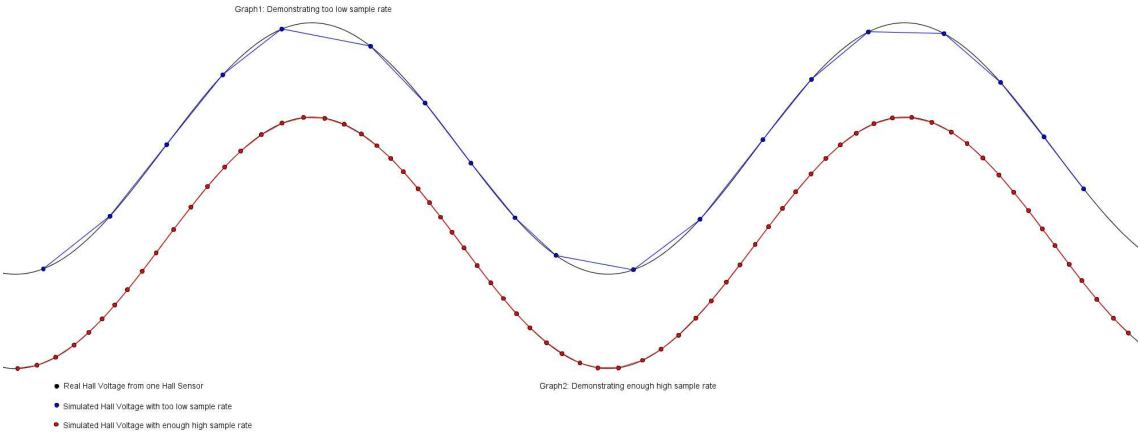

Figure 7: Hall voltage simulation sampling rate

The ADCs that the object board has are not ideal. They also have the same problem as the DACs that should be used for simulation although the ADCs also read the real Hall voltage. Thus to get enough accurate simulations the DACs need to be faster than the

ADCs. The PCM1602A DAC has a two decade higher sampling rate and two times higher resolution than the ADCs used in the object board, so it might be fast enough for simulating the Hall voltage.

6 Results

This thesis describes an investigation project which analyzed the possibilities for simulating different kinds of interfaces. As earlier mentioned, the project mostly concentrated on studying RFIDs but also the physics of the Hall effect and the possibilities of simulating the Hall voltage for ADCs were considered very carefully.

Firstly, simulating RFID was a difficult task but a success. Even though nothing ready was not implemented that can be started to use right away. The simulation of Texas Instruments' chip worked on some level. Other possibilities that are more similar to real environments were also investigated. These possibilities included using two chips, one for simulating the data of RFID tags and one for its real purpose, which is reading the data of RFID tags, is something that could be usable in the future. Also using a complete solution such as the RFID tag emulators is something that definitely requires consideration, and it would be interesting to investigate the possibilities in this kind of a project.

Secondly, the Hall effect simulation was pretty easy from the beginning of this project. There are several different ways to simulate AC voltage for ADCs and the best and cheapest way to do this in an embedded environment is using DACs. Their cost is minimal if compared for example to voltage generators.

Overall, the project was a success because now all the information is available for someone who starts implementing the simulations for testing environments. All the hard work is done and now there is a clear path for implementing this project.

7 Conclusion

After several months of investigation and implementation the study described in this thesis has been completed. As a result, the thesis illustrates several possible methods for simulating RFID tags and the Hall voltage for the object system. Some of the methods are more difficult to implement than the others. However, the thesis considers the advantages and disadvantages of every method.

The Hall voltage simulation with DACs worked on a theoretical level. There might be difficulties in the implementation, but the Hall voltage simulation will definitely be feasible. Furthermore, RFID simulation was shown to work also in practice. In the project RFID simulation was done by simulating the RFID transceiver’s SPI interface for the object board’s microcontroller. However, the other possibilities to do the simulation were also considered.

When writing the conclusion for the thesis, KONE had started to implement the simulation board. And surprisingly the work done in the project did not go to waste. At the moment, the idea is to carry out the RFID simulation by simulating Texas Instruments’ chip by a microcontroller. Furthermore the Hall effect simulation will be done with DACs. There will definitely still be problems in the implementation but it is certain that the project will be feasible and ready in the near future.

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