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הפקולטה למדעי ההנדסה  
המחלקה להנדסת חשמל ומחשבים

Four Year Engineering Project

Preliminary Design Report

**Computerized drive for permanent magnets in a spectroscopic setup**

Project number: p-2022-048

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1. **Abstract**

Computerized drive for permanent magnets in a spectroscopic setup  
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* 1. **English Abstract**

In the future days, we might not be able to solve every problem with Silicon, therefore the desire to research other materials grows. For that, precise measurements tools that can measure in conditions of a magnetic field in a Faraday cage are required. As a result, the purpose of the project will be to measure the wanted values under the wanted conditions.  
The innovation of this measurement tool is the first measurement tool that measures in conditions of a magnetic field in a Faraday cage that is controlled automatically from distance.  
The suggested method consists of an FPGA microprocessor, Step motor, LEDs, power supplier, electric board, Interface, Infrared sensors, conveyor belt, Rare Earth Magnet, and a Shock Absorber which together be the precise measurement tool.  
The expected result is a working system that can take precise measurements under the desirable controlled conditions.  
Keywords: Magnet, Rare Earth Magnet, FPGA Microprocessor, Step motor, Hall effect, LabView, Position Sensors.

**1.2 Hebrew Abstract**

בעתיד לא בטוח שיהיה ניתן לפתור כל בעיה עם סיליקון ולכן הרצון לחקור חומרים ודגמים שונים תמיד יהיה קיים. לשם כך נדרשות מערכות מדידה שיכולות למדוד את הרכיבים בתנאים של שדה מגנטי ובתוך כלוב פאראדיי הנשלטים מרחוק בדיוק רב.   
בעקבות כך המטרה של מכשיר המדידה תהיה לדעת למדוד את התכונות הרצויות תוך מתן תנאים רצויים.   
החדשנות היא בכך שלא קיים כיום כלי מדידה המבצע את המדידות לצד שדה מגנטי בתוך כלוב פאראדיי המבודד ספקטרום של כל גלי האור הלא רצויים (מלבד אורך הגל הרצוי) שניתן לשלוט עליו מרחוק.  
המתודה המוצעת היא שילוב של הרכיבים הבאים: מיקרו בקר, מנוע צעד, כרטיס המיועד להתממשק עם המנוע ולהפעיל אותו, לדים להמחשת מיקום המודל, ספק מתח מתאים, חיישני אינפרא אדום, מעגל מודפס המחבר בין הבקר לחיישנים, למתחי הספק ולנגדים חיצוניים , בולם זעזועים, מסוע ודגם שנמצא במרכז המסוע. התוצאה שאנו מצפים לה היא מערכת עובדת שניתן לבצע איתה מדידות בתנאים הרצויים הנשלטת על ידי תוכנת מדידה חיצונית.  
מילות מפתח: מגנט עופרת נדירה, מגנט, מיקרו-בקר, מנוע צעד, אפקט הול, חיישני מיקום, lab-view.

**2. Projects’ purpose**  
The semiconductors field is in continuous progress and some researchers try to find materials that can solve problems that Silicon cannot, for this reason, they need a variety of different and unique measurement tools. Some tools measure magnetic fields like Hall effect sensors, Magnetometers, etc. But a tool that takes measurements under conditions of changing magnetic field for specific wavelengths yet to exist. Our projects’ purpose is to answer that need and build a measurement device that can take measurements from distance in an isolated system under conditions of changing magnetic fields for specific wavelengths.

Our indicators for success would be the functionality and reliability of the result.

**3. Specification sheet**  
**Computerized drive for permanent magnets in a spectroscopic setup**

The purpose of the project is to create an automatic measurement tool, controlled from distance, that can take measurements with different strengths of a magnetic field inside a Faraday cage.  
The reason that we use Rare Earth Magnet and not Electromagnet like Hall Effect measurement tools usually used with is that the Rare Earth Magnet is smaller and cheaper, so it is perfect for our circumstances. In addition, Electromagnet must be extremely cold because it is a Super Conductor.  
The only disadvantage of Rare Earth Magnet is that we can’t control its magnetic field with electricity, and the solution is to build a conveyor belt and control the distance from the model because the magnetic field weakens as the distance grows ( ). So we control the magnetic field with distance and not with electricity.

**3.1 Technology and methodology**

The included technologies in our project are electrical devices that can drive the magnet on the conveyor belt (or devices that can support them) which also can be controlled from distance.  
The work methodology is to separate the project into several smaller tasks, generally decide and understand how the solution for every task should be, and finally assemble all the tasks properly.

**3.2 Work Phases**

1) Buy all the necessary parts and devices

2) Achieve a deep level of understanding of the devices to integrate them properly.

3) Integrate the devices and parts.

5) Program the FPGA micro-processor.

6) Design and print the interface board to connect between the devices.

7) Finalize the project by organizing the parts inside the Faraday cage.

**3.3 Applications of the product**

The application of the project would be to be a part of a system that can measure research models under the desired conditions of magnetic fields and isolation of light.

**3.4 Performances specification**

The system will take as inputs a regular power supply and a signal which specifies if the magnet would be close to the measured model or far away from it. Its’ output would be the magnet location shown on LEDs screens that are visible from the outside in addition to the magnet movements inside of the Faraday cage. It should operate in a way that wouldn’t make much noise and physical disturbances to the system (which is sensitive and need to be reliable over time) and preferably with a fast response time to the inputs.

**3.5 Schematic of system**

Diagram

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**4. Literary review**The first approach we thought about was using an electromagnet [1] because it is the common solution for problems that require changing magnetic fields strengths. An electromagnet is a magnet that can be controlled by an electric current. However, we concluded that since the electromagnet heats up due to the power it consumes and the fact that it needs to operate in low temperatures to be conductive, it needs a cooling system that can satisfy those demands and that in addition to its size, makes it expensive.  
Since we concluded that we won’t use a stationary magnet to solve the issue of the need to change the magnetic field, we will use a moving mechanism in the system because the farther away the model will be from the (permanent) magnets, the weaker the magnetic field will be.   
Therefore, the approach we took was to have a permanent magnet[2] in our system supported by a way to move it farther or closer to our measured model, it solved the problems from the first approach since we don’t need a cooling system and we are using a Rare Earth Magnet material so that the size of the magnet is smaller than the electromagnet, this approach does require more elements to the system like a step motor, sensors, etc. but we managed to solve those problems, therefore, this approach was the way we decided to solve the problem.

**5. Proposal Plan**

Diagram, schematic

Description automatically generatedThe following is a proposal of the final system:

Detailed explanation on every part of the system:

Sensors:

The sensor is an integrated circuit that is described by the following schematic:

Diagram, schematic

Description automatically generated

We can see that the connections to the sensor are supply voltages, input connection to a resistor to bias the LED, and an output connection, the pull-up resistor between pins 3,4 of the sensor are not needed to be placed on the final board since the PSoC microprocessor has a resistive pull-up input option.

The sensor method of operation is that the LED emits light, and the step motor can either block the light or not depending on its location, therefore changing the output voltage.

PSoC microprocessor:

The microprocessor integrates the needed signals, and the processing is described by C language code that is written to it using the PSoC creator FPGA program.

We use the general-purpose I/O pins of the microprocessor with different options, for example, the sensors inputs are resistive pull-up and the magnets’ location user input is a high impedance input, those options help to match the signal to the microprocessor correctly.

PC-837:

As seen by the schematic, the PC837 component is a buffer that floats the inner circuit and does not load the connector. Its method of operation is like the sensor and consists of a diode that emits light whenever enough current is driven through it or, equivalently, is under a large enough voltage difference, the light reaches a transistor and causes a voltage difference.

STK6722H:

The Stepper motor driver receives supply voltages of 36V and drives the step motor according to the inputs of the step motor controller component TD62803P

TD62803P:

The Stepper motor controller receives generates signals for the driver to move the step motor according to the input signals which are described by the following function table:

A picture containing text, crossword puzzle, receipt

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We can move the step motor in the clockwise or counterclockwise direction by having one of the ck1\ck2 pins receive pulses and the other one has constant voltage, the CW/CCW pin is connected to the ground in the interface.

LEDs:

The LEDs component is an integrated circuit that receives the supply voltage of 5V and inputs from the microprocessor about the magnets’ location (which can be known using the sensors and user input) and is displaying the magnets’ location using LEDs.

**6. Constraints**

The constraints of the project are:

* 1. The system will need to be controllable from distance.
  2. The system contains a moving magnet. Therefore, we will need to make sure there are not physical disruptions.

**7. Assumptions**

The assumptions of the project are:

1. We assume that the “steps” of the step motor will be close enough to the continuous distance for sufficient precise measurement.
2. We assume that the FPGA will be able to support the logic needed for the rest of the system, i.e., it should be able to produce and process the signals needed to operate the electrical devices that drive the step motor.
3. We assume that the maximal distance of the magnet from our model, which will be determined by the conveyor belt we will choose to use, which will correspond to the minimal magnetic field strength will be weak enough to be negligible for our measurements.

In case those assumptions will turn out as incorrect, we will need to decide on different devices for the system, for example, a different FPGA microprocessor or even an ASIC circuit.

**8. Risks**

The magnetic field combined with the step motor momentum can make the conveyor belt shake in a way that is not sustainable as a closed system or cannot enable accurate measurements of the model.

**9. Project contents**

The product we provide is a system of a moving magnet with a model holder.  
In addition to that, the system can be supported in a casing that will isolate light and electromagnetic disruptions and hold the system in a way that prevents physical disruptions.  
The limitations of the system are the size of the model we can fit in, the range of the strength of the magnetic field since we use a permanent magnet that is limited by its distance from the model, and therefore the magnetic field strength will be limited.

**10. Final tests proposals**

The product we provide is a system of a moving magnet with a model holder, which is placed inside an isolated box. To verify that the system functions properly we will first need to use it outside of the box to see that the result for each input is correct, for example, if we send the signal for the magnet to move to the models’ location, we will verify it by seeing that it moves there. We will also verify that the LEDs are responding correctly to the magnets’ movement. Afterward, we will verify that the system works inside the isolated box by using the LEDs.

**11. Estimated budget**

|  |  |  |
| --- | --- | --- |
| **Product** | **Price** | **Source** |
| FPGA Cypress CY8CKIT-059 PSoC 5LP Prototyping Kit. model: CY8C5888LTI-LP097 | 10$ | https://www.cypress.com/documentation/development-kitsboards/cy8ckit-059-psoc-5lp-prototyping-kit-onboard-programmer-and |
| Step Motor SST55D3C020 SHINANO KENSHI CO.LTS.JAPAN | 15$ | https://www.ebay.com/itm/265166457228 |
| Nikon 2s700-601 PCB Pulse Motor Drive | 440$ | https://www.ebay.com/p/1637081306 |
| Power Suppliers 220V/36V TDK-Lambda SCB | 167$ | https://il.farnell.com/tdk-lambda/gws-250-36/psu-switch-mode-36v-250w/dp/1996025 |
| Power Suppliers 220V/5V TDK-Lambda SCB | 45$ | https://il.farnell.com/tdk-lambda/ls150-5/psu-enclosed-5v-26a-150w/dp/1657459 |
| Infra-red Sensors Nikon J1 | 8$ |  |
| Rare Earth Magnet | 8$ | https://www.aliexpress.com/item/32824638879.html |
| Conveyor belt | 25$ |  |
| LEDS PCB | 12$ |  |
| Breadboard | 6$ | https://www.amazon.com/4Pcs-MCIGICM-Point-Solderless-Breadboard/dp/B08115P2T4 |

**To sum up, the estimated budget including overhead is 730$ (while the overhead is 25%)**

**12. References**

*[1] “The National High Magnetic Field Laboratory”* [*https://nationalmaglab.org/education/magnet-academy/learn-the-basics/stories/magnets-from-mini-to-mighty*](https://nationalmaglab.org/education/magnet-academy/learn-the-basics/stories/magnets-from-mini-to-mighty)

[2] Cullity, B. D., Graham, C. D. (2008). Introduction to Magnetic Materials. Wiley-IEEE. p. 489. ISBN 0-471-47741-9.

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