Enabling photodetection electronics for fluorescent diamond based quantum sensing
Project plan

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Contents

Chapter 1

Introduction

This chapter introduces the assignment and some foundational concepts of quantum sensing.

1.1 Background

Nitrogen-vacancy (NV) centers [1] are imperfections in the atomic structure of diamonds, which have the useful property of spin-dependent luminescence. This means that the spin of the NV center affects the frequency of the light emitted by the structure[1]. Using this quality of the NV structure, different environmental metrics (e.g magnetic fields) can be measured.

The Applied Nanotechnology research group is working on a NV-center-based sensor setup. Processing data from the setup requires working with weak signals that are hard to distinguish from the environmental noise. While this is a significant problem, it is also a very common one. Because of this, there is already widely-used system used to isolate signals in such cases: the lock-in amplifier.

1.2 Purpose of the assignment

Implementing a lock-in amplifier is the main purpose of the assignment. To create a complete solution, there are several different functionalities and systems that need to be developed.

Before doing anything else, the raw sensor data needs to be extracted and then fed to a lock-in amplifier. This should be done in a standardized manner, in order to facilitate testing with different devices. After establishing connection, a control interface needs to be implemented. It needs to be programmed so that it can control all necessary features of the lock-in amplifier. Following the development of the program, a custom photodetection circuit needs to be designed. The circuit should accommodate the sensors and lock-in amplifier. Lastly, an OLIA[2] circuit needs to be tested and compared to conventional lock-in systems.

1.3 Assignment specifications

1.4 Methodological approach

[1]The NV center only emits light after absorbing photons, a phenomenon called photoluminescence [2]

[2]Open Lock-In Amplifier (OLIA) is an open-source microcontroller-based lock-in amplifier. It uses common components, which makes it easy to build [3]

Chapter 2

Project boundaries

The project boundaries were initially based on the assignment form, but were later discussed with the client and refined further.

Must have

- OLIA implementation
- Software for signal processing and visualization

Should have

- Tests comparing OLIA to market solutions
- Hardware platform for photodetection

Could have

- Tests with different diamond samples
- Tests with different quantum protocols

Will not have

-

Chapter 3

Products and project objectives

This chapter describes all the required products and based on them sets up the objectives for the project.

3.1 Products

There are several technical products that need to be delivered, all of which fall into the categories of hardware, software and test data.

Developing a hardware platform for measurements is the most important part of the project. An OLIA needs to be built using the available schematics. Afterwards, a printed circuit board (PCB) combining the OLIA with a photodiode subsystem.

In terms of software, an application needs to be developed to process and visualize the signal readouts from a lock-in amplifier. It should be able to retrieve data from different lock-in amplifiers. Preferably. it should be written in Python, MATLAB or HTML. If necessary, modifications to the OLIA firmware will also be made.

Lastly, test data also needs to be delivered to the client in a digestible manner. This data should compare the OLIA solution to different lock-in systems available on the market. The most important metrics are signal-to-noise ration (SNR), bandwidth and stability. If there is enough time at the end of the project, tests with different diamond samples and alternative quantum protocols can be done.

3.1.1 Goals

Based on the MoSCoW priorities from Chapter 2, a set of goals was created to further specify all items from each prioritization category. Every goal was designed so that its outcome results in a tangible project milestone (e.g. a deliverable).

- **Goal 1**: Create a hardware setup, which measures and amplifies photodiode signals
- **Goal 2**: Develop software to process and visualize lock-in amplifier signals
- **Goal 3**: Compare the performance of different lock-in amplifiers

While these goals are practical, they are still not specific enough. To eliminate the possibility of confusion, a set of tasks were created. All tasks contribute to one of the three goals.

- **Task 1.1**: Build an operable OLIA
- **Task 1.2**: Design a photodiode PCB, which can accommodate different lock-in amplifiers
- **Task 2.1**: Develop software that acquires signals and is then able to visualize them
- **Task 3.1**: Use key performance metrics to compare the OLIA implementation to market solutions
- **Task 3.2**: Measure OLIA performance using different diamond samples and quantum protocols

Task 1.1 is to build an OLIA amplifier, which can be used at Applied Nanotechnology's laboratory. This will be done with the technical specifications and firmware provided by Harvie and de Mello [3].

Task 1.2 is the follow-up to **task 1.1**. It involves the design and production of a photodiode PCB. The PCB has to output signals that are not only compatible with the OLIA, but also with lock-in amplifiers that are available on the market.

Task 2.1 is to write a application in Python, MATLAB or alternatively create an HTML-based web application. This can be done on a different setup, but ideally it will use the hardware setup from **goal 1**.

Task 3.1 follows after all previous tasks. The completed setup needs to be used to measure the performance of OLIA and compare it to other lock-in amplifiers available on the market. SNR, bandwidth and stability are the main metrics that need to be compared.

Task 3.2 is similar to **task 3.1**, but it is a much broader exploration of the OLIA implementation's performance. Using different diamond samples and quantum protocols will show how the amplifier performs and how different conditions affect it. Because the task can be used to verify the setup from **goal 1**, it can also be done before **task 3.1**.

3.1.2 Deliverables

1.

Chapter 4

Project activities

4.1 Start phase

4.2 Realization phase

4.3 End phase

Chapter 5

Quality assurance

Chapter 6

Project organization

6.1 Organization

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Vladislav Serafimov	v.serafimov@saxion.nl	Student
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Table 6.1: People involved in the project

6.2 Communication

Chapter 7

Planning

Chapter 8

Risk analysis

Bibliography

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[2] Wikipedia contributors, *Photoluminescence — Wikipedia, the free encyclopedia*, https://en.wikipedia.org/w/index.php?title=Photoluminescence&oldid=1309081879, [Online; accessed 4-September-2025], 2025.

[3] A. J. Harvie and J. C. de Mello, "Olia: An open-source digital lock-in amplifier," *Frontiers in Sensors*, vol. 4, p. 1 102 176, 2023.