GAUSS SENSOR FOR MAGNET ARRAY FILTER

Design Document

TEAM NUMBER : SDMAY 20-27

CLIENT : MAGNET ARRAY COMPANY

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Development Standards & Practices Used

- Circuits standards
  - Within safe power rating
  - IEEE 1522-2004 - IEEE Standard for Testability and Diagnosability Characteristics and Metrics
- Software Development Standards
  - Accuracy in taking measurements
  - Reliability in procuring data
  - Establishment of specific or custom software for designing,fabrication and installation

Summary of Requirements

Functional Requirements:

- Sensor able to detect magnetic particles up to 0.05 μm
- Able to detect iron particles
- Resistant to continuous vibration and temperature changes
- Able to withstand heat and vibration

Economic Requirements

- Able to detect when then buildups reach the threshold, indicating the time to change the filter, decreasing the amount of time and money used to gradually check and changing the filter.
- With the ability to know when the filter is full allows consumer to make sure metal is not going through system increasing life of engine.
- Minimal impact design standard

Applicable Courses from Iowa State University Curriculum

EE 201/230/285/332/330/333

CPR E 185/281/288

New Skills/Knowledge acquired that was not taught in courses

- HTML Programming
- Usage of Gauss meter

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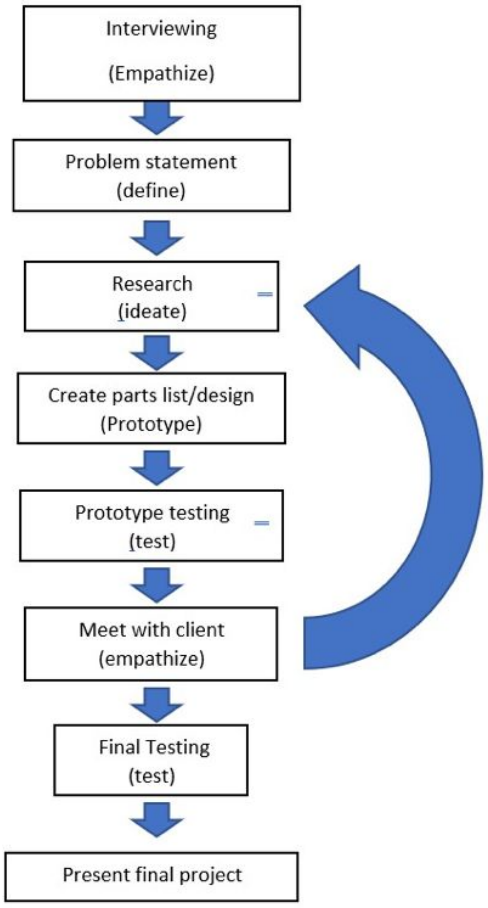


Project Plan

1. The first part of the project is to gain information from the client which is apart from the empathizing stage. This step is done in order to really know the problem the client is facing and discussing the expected outcomes.

2. The second step is the defining the problem statement. After receiving the information from the client, the team should formulate a thorough problem statement which would represent the problem the client is trying to solve and the expected outcome.

3. The third step is ideate which is where the team does research and collect data that could help in solving the problem. This step is where the team brainstorm ideas and connecting them all together.

4. The fourth step is where the team collects the required parts in order to build a prototype based on the ideas generated earlier.

5. The fifth step is where the team conducts rigorous testing on the prototype and prove that the solution works.

6. After requiring a possible solution, the team should present it to the client and receive feedback. If the requirements are not met, the team should go back to the ideate stage and formulate a new plan to tackle the problem.

7. If the client is satisfied with the outcome, the team should conduct a final testing on the final product to endure the quality of the product.

8. After the final testing, the team should present the product to the client and public. At this step, the team should be confident that a quality final product is made.

1 Introduction

1.1 Acknowledgement

We would like to acknowledge the help from the following people and organizations:

Magnet Array Company, Dennis O'neel, Dr. Mani Mina, Dr. Brian Stewart, Wei Shen Thea, Texas Instruments, Honeywell, Dr. Akilesh Tyagi, Dr. Joseph Zambreno

1.2 Problem and Project Statement

General Problem Statement:

A problem with closed systems is contaminants that can build within a mechanical system because with moving parts there will always be slight wear with the components that leads to particles traveling through the system. The filter for a vehicle helps to try and trap these particles but is not very effective for small contaminants. Thus the magnetic array filter acts as a second barrier in trapping these contaminants in the filter. Currently there is still no way of knowing when the filter has reached a certain threshold to where particles will not be caught. Our project is to design a sensor that is able to accurately determine when this threshold is reached and alert the user that it is time to change the filter.

General Solution Approach

To solve this problem, the team has to build a sensor array that works in conjunction with a microcontroller to alert the user when it is time to replace the filter. This will better protect their machinery and increase its life time.

1.3 Operational Environment

The magnetic field sensor created will have to withstand typical vibration found in combustion engines and hydraulic equipment. The sensor would also have to withstand wide temperature fluctuation existing in the combustion engine. The sensor would be used on a car engine, which is expected to be exposed to different weather conditions according to the season of the year. For example, the sensor would be expected to withstand extreme low temperature during winter, to withstand extremely high temperature during summer, to have water resistivity during rainy seasons, to withstand dusty sand from the road etc.

1.4 Requirements

For our project, the requirements intended includes functional and economic regarding the sensor that is to be designed.

First of all, in the aspect of functional requirements, the sensor has to be able to detect magnetic particles down to 0.05 microns. Additionally, our sensor also has to be able to detect iron with high accuracy. Also, depending on time availability, a plausible additional functionality would include detecting brass and aluminum particles through the system. Our design also has to be resistant to continuous mechanical vibration and frequent temperature changes ranging from ambient to 200 F. The sensor has to detect the particle buildup and accurately depict when it reaches a certain threshold. It should also inform the user if there is a huge jump in particle buildup to indicate a pending catastrophic failure of the system.

In terms of economic requirements, the sensor should be able to detect iron, brass and aluminum particle buildup and informs the user of the current level. The idea of it is to indicate the predicted time to change the filter, thus decreasing the amount of time and money used to gradually check, change and replace the filter. It is important for consumers to make certain that no metals from the friction at sliding interfaces in combustion engines do not seep through the whole engine that could damage the whole system.

Before, the user would have to frequently do an inspection manually on the filter and it took time on it. Not to mention, it is an inefficient way to make certain of the “exact” time to change the filter. Hence, with help from the sensor, it should have the ability to inform the user of the current buildup; and if the threshold is reached, the filter can be replaced at optimal periods, thus increasing the life expectancy of the machine and improve the efficiency of the overall maintenance process.

1.5 Intended Users and Uses

The intended users of our product are the drivers of motor vehicles. The sensor created would be expected to be able to monitor the change in magnetic field inside the machinery spin-ons filter, which is correlated to the iron particles accumulation in the filter. It is also expected that the sensor created should report the degree of iron particle accumulation to the microprocessors on the vehicle to help the car users to keep them updated about the situation of the car filter..

1.6 Assumptions and Limitations

Our board will have to withstand rapid temperature changes from ambient to 200 degrees Fahrenheit
This board will first be tested on the benches provided by Dr.Brian then we will look into implementations in machinary most likely as an LED indicator on the dashboard.

The board will have a voltage rating of 12-24V
Currently we will not be able to test the field with increasing temperatures accurately because we will not have direct access to a vehicle.

1.7 Expected End Product and Deliverables

1. **Sensor array for Magnetic Array Filter**

   The sensor array filter is designed specifically for the Magnetic Array Filter (MAF) that serves as a complement in utilizing the MAF to its full capacity on industrial and commercial usage. The sensor array functions in detecting the amount of particle build up in the magnetic filter. The sensor works with the hall effect sensor to monitor the changes in magnetic field on the filter that is mostly caused by the accumulation of metal particles -- mostly iron. With this, the sensor can detect the amount of metal amassing inside the filter.

   The data collected by the sensor will also be directed to the user for their information. With a set amount of threshold, they will have a clear indication on the level of the build up inside the filter, and depict the appropriate time to change them -- increasing the feasibility and efficiency of the MAF.

2. **User's Manual**

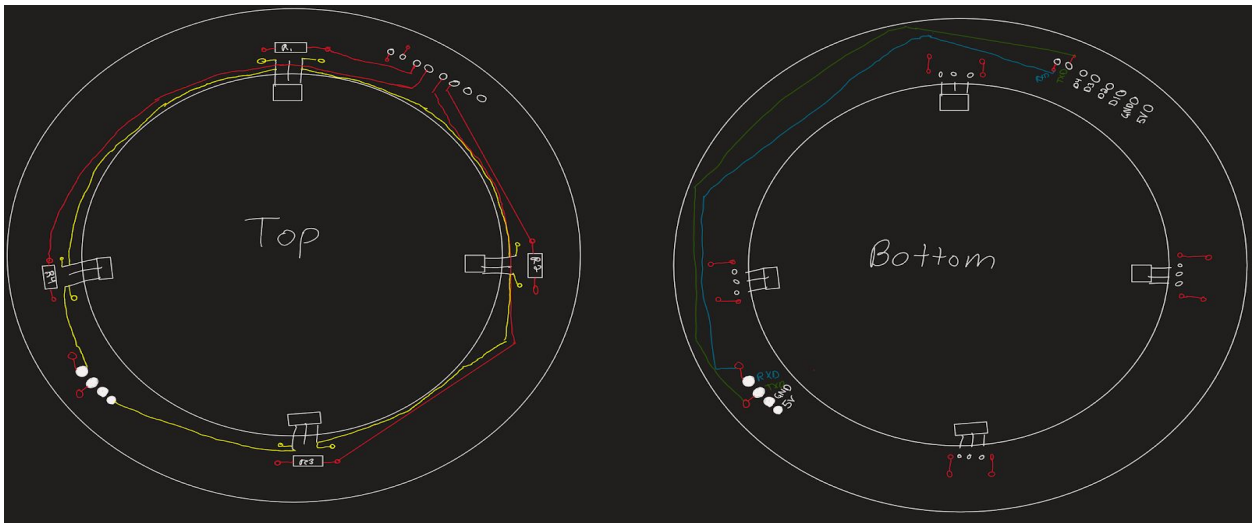
   The client will be provided with a clear and concise User's Manual of the completed sensor for the Magnetic Array Filter. The user's manual will serve as a guidebook on providing summary and overall information relating the presented product, detailed manual on steps of utilizing the sensor in the filter, and other miscellaneous related to the sensor.

2. Specifications and Analysis

2.1 Proposed Design

Include any/all possible methods of approach to solving the problem:

For our initial prototype we plan on designing a ring shaped PCB that will sit on top of the collar when it is connected to an oil filter. This will allow the hall effect sensors to lay off the inside of the ring and fit within the collar and oil filter. It will allow us to hopefully get more accurate changes with the magnetic field. We will also be using two different types of hall effect sensors to see which one will be more accurate for our purposes. The board will also have pin outs that can be directly connected to an arduino that will be used to collect the changes in field.



2.2 Design Analysis

Thus far, our team has drafted a design of a prototype and we are looking into possible parts as well as circuit designs that could be incorporated into the design. Currently, we are looking for possible hall effect sensors from Texas Instruments and Honeywell. We acquired some samples which includes DRV5053, DRV5056, DRV5057 from Texas Instruments and SS49 and SS49ET from Honeywell.

Besides that, we have not done any testing yet as we are still in the process of ideating. However, after finishing our prototype, we should test it using a testbench that was constructed by Dr. Brian in his lab. The testbench consists of tubes and a filter where contaminated oil will run through the filter which is fitted with the magnetic array. After testing, we should have an idea on how to improve our design.

One of the advantages of our proposed design is it could be easily installed as it just needs to be placed on top of the magnet array. This makes our sensor easily accessible to the user which eases the user to abstract data/information from the sensor.

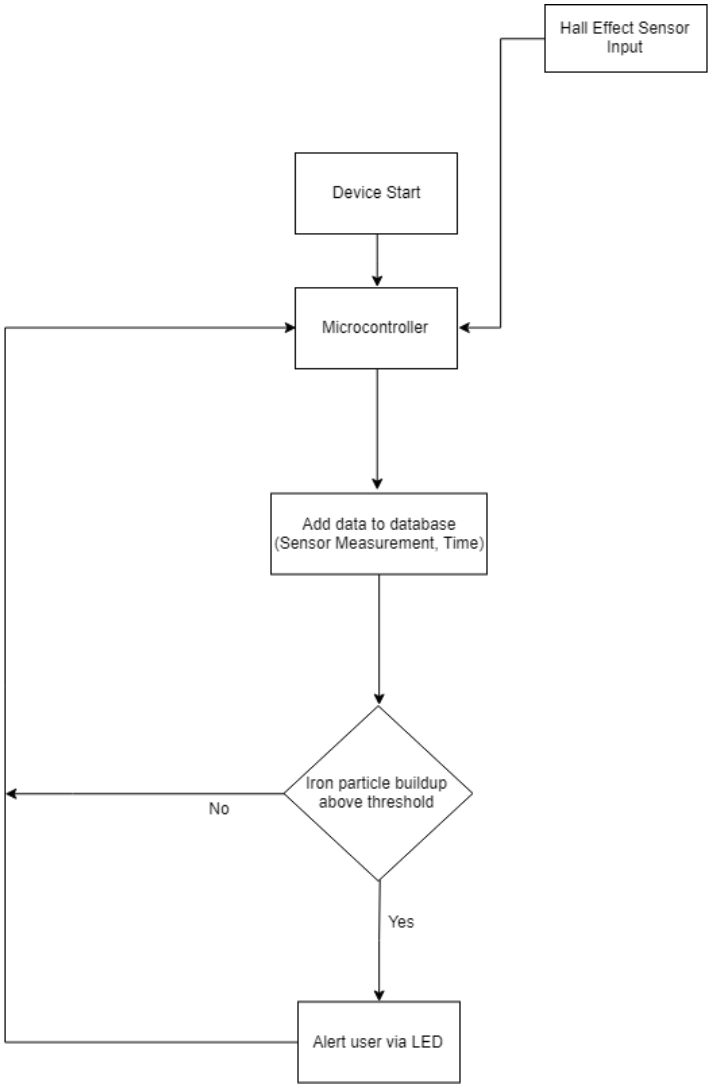
2.3 Development Process

The development process used for this project is Agile. Our Agile process is as follows: Initiation of project followed by a team meeting. Then, it is followed by development of the sensor. We will then gather data based on our initial readings. It is then followed by internal evaluation. Then, we will go back to team meeting then development and evaluation. Then, we will have it evaluated by our client. In between all of these processes, reports are made and recorded.

2.4 Design Plan

First, we identify the problem to be solved, which is stated in our problem statement. Then, we gather the information from client and end-users regarding the product limitations and requirements. Then, research is done by the team regarding issues that has to be solved and product end design is drafted. Then, possible solutions are thought about by the team members and discussed. The product feasibility is also discussed during this session. Then, a prototype design is selected and built. After that, testing is done and any problems that surface is discussed and the whole cycle restarts.

We will use three sensors in our initial testing that are not affected as much by temperature fluctuations and vibration which are Texas Instruments DRV5055, DRV5056, DRV5057. Then, we will design a circular PCB board that can be attached to the Magnet Array Filter. The PCB board is connected to a microcontroller that collects analog data from the sensor. The microcontroller will then decide whether the amount of particle buildup has reached the threshold. In the software design, we will take the input from the sensor and save it to a local database. The database data is tracked and if a sudden fluctuation is recorded, the alert will be sent to the user as well. Thus, there are 2 instances where the user will be alerted, which are when the threshold is reached, and if there is a sudden fluctuation in particle build up indicating a terminal failure. The microcontroller and sensor will use 12-24V inputs from the vehicle battery or the machinery that it is attached to. The microcontroller will be attached to a location away from the sensor via wires to avoid temperature changes and vibration to it. The following diagram is used in the microcontroller:


Hall Effect Sensor Input
Device Start
Microcontroller
Add data to database (Sensor Measurement, Time)
Iron particle buildup above threshold
No
Yes
Alert user via LED