

Power Frequency Magnetic Field Sensor

KARUNARATNE A.G.S.I.

*Department of Electrical and Electronic
Engineering
University of Peradeniya
Sri Lanka
e20192@eng.pdn.ac.lk*

WAHALATHANTRI T.N.

*Department of Electrical and Electronic
Engineering
University of Peradeniya
Sri Lanka
e20418@eng.pdn.ac.lk*

WICKRAMASINGHE R.T.

*Department of Electrical and Electronic
Engineering
University of Peradeniya
Sri Lanka
e20440@eng.pdn.ac.lk*

Abstract—This project focuses on developing a sensor aimed at remotely detecting power-frequency magnetic fields, particularly those emanating from sources such as high-tension lines and substations, posing potential hazards to humans. The objective is to design a sensor capable of accurately measuring magnetic field levels. Utilizing a linear Hall effect sensor, the project converts magnetic field intensity into voltage output, which is subsequently processed by an Arduino microcontroller to quantify the field strength in Gauss units. The sensor's range spans from 0 to 700 Gauss, accommodating positive and negative magnetic fields. Results are displayed on an LCD screen, providing real-time feedback on magnetic field levels, thus contributing to improved safety measures in environments where exposure to such fields is a concern.

Keywords—sensor, power-frequency, magnetic, strength

I. INTRODUCTION

The objective of this project is to design a sensor to detect the magnetic field level and measure the strength of that magnetic field. At the beginning of the project, as an initial approach, research was done to find some commercially available sensors and different principles that fulfill this objective. In light of this research, it was found that magnetometers and magnetoresistance sensors are prominent in the market. Some used principles were magnetostriction property, electromagnetic induction, and optical properties. Out of these methods, we decided to use a modern technology method as the use of microcontrollers for the sensor. (Dilip Raja, 2015)

The main aim of this project is to generate an electrical signal from a physical variable. All electrical and electronic engineers are capable of doing that. In this project, the physical variable is the magnetic field and the electrical signal is a voltage signal. For this conversion, the SS49E hall effect sensor is used. It generates an analog voltage output in the presence of a magnetic field. This output is highly varying. To filter those variations, capacitors are used. Then, an Arduino microcontroller is used to store the output signal and display it on an LCD. The initial version of this sensor is capable of measuring values in the range of -650 to +650 Gauss.

The application of this project is to make a device that measures the magnetic field strength of Power frequency magnetic fields. It is believed that these PFMFs are hazardous to human health. Some countries have already implemented

guidelines for PFMF exposure. (Maalej, 2011) So, this sensor will measure the strength of PFMFs and give a warning when the value exceeds the human exposure limits for PFMFs.

II. INITIAL SPECIFICATIONS

A. Measurement Quality

This sensor provides a voltage output of 2.7mV for 1 Gauss of magnetic field, indicating the sensitivity is 2.7mV/G. This value is good for the PFMF measurements since they are very sensitive. Other than that, this sensor can measure both positive and negative(opposite direction) magnetic fields stating that it is bipolar. So, if the direction of the magnetic field is changed, the reading will be minus on the display.

B. Range

The sensor design has a range of -650 to 650 Gauss which corresponds to an output voltage range of 0.86 to 4.21 V. This means, the sensor will output a voltage of 4.21 V in the presence of a 650 Gauss magnetic field and 0.86 V to a magnetic field of -650 Gauss. Also, there will be an output voltage of 2.5 V for 0 Gauss condition.

C. Resolution

The resolution of the design is 0.01 Gauss. This value can be improved in future designs by using an amplifier circuit which is used to obtain a voltage gain as well as by using another SS49E and considering the average.

D. Other Specifications

- Operating Temperature: - 40 °C to 150 °C
- Operating Voltage: 4.5 V to 6 V
- Offset Error: 0.55 Gauss
- Length of SS49E: 12 mm
- Dimensions of the compartment: 7 cm × 15 cm
- 16 × 2 LCD with I2C module

III. METHOD

As mentioned in the introduction, the method used in developing the sensor was a combination of an Arduino microcontroller and a Hall effect sensor.

A. Circuit Diagrams

Before implementing the circuit physically, we simulated the circuit on *Proteus 8 software* to check whether the magnetic field can be measured using Arduino controllers.

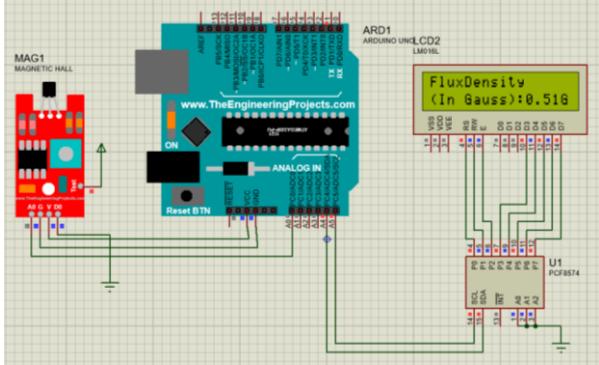


Figure 1: Proteus simulation setup.

Figure 1 consists of components, a linear hall effect sensor module, an Arduino Uno, an I/O expander, and an LCD module. An imaginary magnetic field input is given to the sensor module and the value is observed on the LCD. This helped us a lot to plan implementing the circuit design physically.

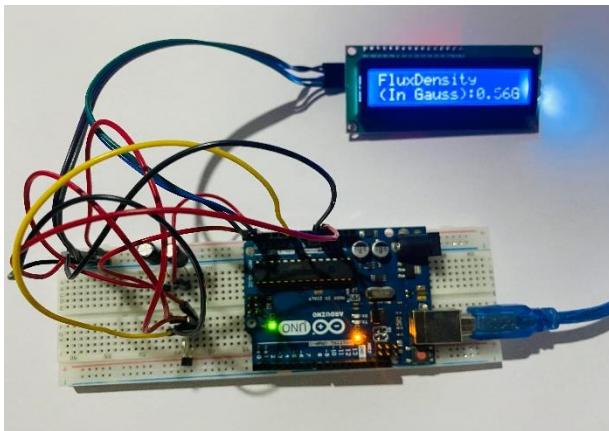


Figure 2: Circuit Setup for the Sensor Design

Figure 2 depicts the physical circuit setup that is used for the magnetic field sensor. It has an SS49E linear hall sensor, two capacitors, an Arduino Uno, and a 16×2 LCD.

B. Principle of Operation

When a magnetic field comes in contact with the SS49E, it generates a voltage. The maximum voltage output would be 4.21 V which is for a magnetic field of 650 Gauss. As shown in Figure 3, there are three pins in the SS49E. Pin 1 is for V_{cc} , pin 2 is for GND, and pin 3 is for V_{out} . The branded surface of the SS49E shows a positive output for the South pole and a negative output for the North pole. (Hareendran, 2019) For the operation of the SS49E, a V_{cc} should be applied. (“SS49E datasheet,” 2022) There can be several noises interfering with the output

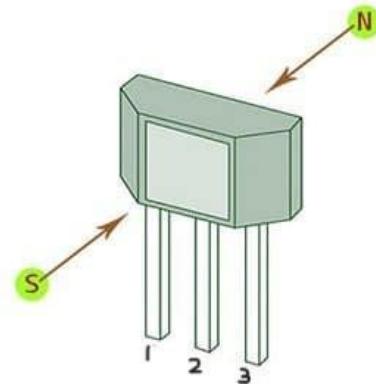


Figure 3: Active region of the SS49E. (Source: Hareendran, 2019)

voltage signal due to the presence of so many wires in the circuit setup. To avoid those interferences, two capacitors are used. Then, the filtered output voltage is directed to the Arduino Uno, and it computes this voltage output and displays it on the LCD as a value in Gauss using the sensitivity of the sensor. The code

```
ARDUINO_Sketch\Sketch.ino
1 // This sketch reads the analog output from the SS49E Hall Effect Sensor
2 // and converts it to a digital reading. The digital reading is then converted
3 // to a flux density value in Gauss and displayed on the LCD.
4 // The sensor has a resolution of 10 bits, so for every 1/1024 = 1.000, we get one increment
5 // in Gauss. So, we need to divide the value by 1.000 for getting the gauss value, now the 0.1 gauss output of sensor is also to be subtracted that is, to hold 2 or more Gauss (Total - 2)
6
7 // Turn on the backlight and read a message.
8 void setup() {
9   // Set the LCD address to 0x27 for a 16 chars and 2 line display
10  lcd.begin(0x27);
11  // Set the contrast using软件
12  analogWrite(0x40, 0);
13
14  // Set the back light
15  backLight();
16
17  // Initialize the sensor
18  sensorSetup();
19
20  // Turn on the backlight and read a message.
21  lcd.backlight();
22  lcd.print("FluxDensity");
23  lcd.print(" (In Gauss):");
24
25  // Turn off the back light
26  backLightOff();
27
28  // Read the analog value from the sensor
29  analogValue = analogRead(0);
30
31  // Turn on the back light
32  backLight();
33
34  // Turn on the backlight and read a message.
35  lcd.backlight();
36  lcd.print("FluxDensity");
37  lcd.print(" (In Gauss):");
38
39  // Turn off the back light
40  backLightOff();
41
42  // Turn on the back light
43  backLight();
44
45  // Turn on the backlight and read a message.
46  lcd.backlight();
47  lcd.print("FluxDensity");
48  lcd.print(" (In Gauss):");
49
50  // Turn off the back light
51  backLightOff();
52
53  // Turn on the back light
54  backLight();
55
56  // Turn on the backlight and read a message.
57  lcd.backlight();
58  lcd.print("FluxDensity");
59  lcd.print(" (In Gauss):");
60
61  // Turn off the back light
62  backLightOff();
63
64  // Turn on the back light
65  backLight();
66
67  // Turn on the backlight and read a message.
68  lcd.backlight();
69  lcd.print("FluxDensity");
70  lcd.print(" (In Gauss):");
71
72  // Turn off the back light
73  backLightOff();
74
75  // Turn on the back light
76  backLight();
77
78  // Turn on the backlight and read a message.
79  lcd.backlight();
80  lcd.print("FluxDensity");
81  lcd.print(" (In Gauss):");
82
83  // Turn off the back light
84  backLightOff();
85
86  // Turn on the back light
87  backLight();
88
89  // Turn on the backlight and read a message.
90  lcd.backlight();
91  lcd.print("FluxDensity");
92  lcd.print(" (In Gauss):");
93
94  // Turn off the back light
95  backLightOff();
96
97  // Turn on the back light
98  backLight();
99
100 // Turn on the backlight and read a message.
101 lcd.backlight();
102 lcd.print("FluxDensity");
103 lcd.print(" (In Gauss):");
104
105 // Turn off the back light
106 backLightOff();
107
108 // Turn on the back light
109 backLight();
110
111 // Turn on the backlight and read a message.
112 lcd.backlight();
113 lcd.print("FluxDensity");
114 lcd.print(" (In Gauss):");
115
116 // Turn off the back light
117 backLightOff();
118
119 // Turn on the back light
120 backLight();
121
122 // Turn on the backlight and read a message.
123 lcd.backlight();
124 lcd.print("FluxDensity");
125 lcd.print(" (In Gauss):");
126
127 // Turn off the back light
128 backLightOff();
129
130 // Turn on the back light
131 backLight();
132
133 // Turn on the backlight and read a message.
134 lcd.backlight();
135 lcd.print("FluxDensity");
136 lcd.print(" (In Gauss):");
137
138 // Turn off the back light
139 backLightOff();
140
141 // Turn on the back light
142 backLight();
143
144 // Turn on the backlight and read a message.
145 lcd.backlight();
146 lcd.print("FluxDensity");
147 lcd.print(" (In Gauss):");
148
149 // Turn off the back light
150 backLightOff();
151
152 // Turn on the back light
153 backLight();
154
155 // Turn on the backlight and read a message.
156 lcd.backlight();
157 lcd.print("FluxDensity");
158 lcd.print(" (In Gauss):");
159
160 // Turn off the back light
161 backLightOff();
162
163 // Turn on the back light
164 backLight();
165
166 // Turn on the backlight and read a message.
167 lcd.backlight();
168 lcd.print("FluxDensity");
169 lcd.print(" (In Gauss):");
170
171 // Turn off the back light
172 backLightOff();
173
174 // Turn on the back light
175 backLight();
176
177 // Turn on the backlight and read a message.
178 lcd.backlight();
179 lcd.print("FluxDensity");
180 lcd.print(" (In Gauss):");
181
182 // Turn off the back light
183 backLightOff();
184
185 // Turn on the back light
186 backLight();
187
188 // Turn on the backlight and read a message.
189 lcd.backlight();
190 lcd.print("FluxDensity");
191 lcd.print(" (In Gauss):");
192
193 // Turn off the back light
194 backLightOff();
195
196 // Turn on the back light
197 backLight();
198
199 // Turn on the backlight and read a message.
200 lcd.backlight();
201 lcd.print("FluxDensity");
202 lcd.print(" (In Gauss):");
203
204 // Turn off the back light
205 backLightOff();
206
207 // Turn on the back light
208 backLight();
209
210 // Turn on the backlight and read a message.
211 lcd.backlight();
212 lcd.print("FluxDensity");
213 lcd.print(" (In Gauss):");
214
215 // Turn off the back light
216 backLightOff();
217
218 // Turn on the back light
219 backLight();
220
221 // Turn on the backlight and read a message.
222 lcd.backlight();
223 lcd.print("FluxDensity");
224 lcd.print(" (In Gauss):");
225
226 // Turn off the back light
227 backLightOff();
228
229 // Turn on the back light
230 backLight();
231
232 // Turn on the backlight and read a message.
233 lcd.backlight();
234 lcd.print("FluxDensity");
235 lcd.print(" (In Gauss):");
236
237 // Turn off the back light
238 backLightOff();
239
240 // Turn on the back light
241 backLight();
242
243 // Turn on the backlight and read a message.
244 lcd.backlight();
245 lcd.print("FluxDensity");
246 lcd.print(" (In Gauss):");
247
248 // Turn off the back light
249 backLightOff();
250
251 // Turn on the back light
252 backLight();
253
254 // Turn on the backlight and read a message.
255 lcd.backlight();
256 lcd.print("FluxDensity");
257 lcd.print(" (In Gauss):");
258
259 // Turn off the back light
260 backLightOff();
261
262 // Turn on the back light
263 backLight();
264
265 // Turn on the backlight and read a message.
266 lcd.backlight();
267 lcd.print("FluxDensity");
268 lcd.print(" (In Gauss):");
269
270 // Turn off the back light
271 backLightOff();
272
273 // Turn on the back light
274 backLight();
275
276 // Turn on the backlight and read a message.
277 lcd.backlight();
278 lcd.print("FluxDensity");
279 lcd.print(" (In Gauss):");
280
281 // Turn off the back light
282 backLightOff();
283
284 // Turn on the back light
285 backLight();
286
287 // Turn on the backlight and read a message.
288 lcd.backlight();
289 lcd.print("FluxDensity");
290 lcd.print(" (In Gauss):");
291
292 // Turn off the back light
293 backLightOff();
294
295 // Turn on the back light
296 backLight();
297
298 // Turn on the backlight and read a message.
299 lcd.backlight();
300 lcd.print("FluxDensity");
301 lcd.print(" (In Gauss):");
302
303 // Turn off the back light
304 backLightOff();
305
306 // Turn on the back light
307 backLight();
308
309 // Turn on the backlight and read a message.
310 lcd.backlight();
311 lcd.print("FluxDensity");
312 lcd.print(" (In Gauss):");
313
314 // Turn off the back light
315 backLightOff();
316
317 // Turn on the back light
318 backLight();
319
320 // Turn on the backlight and read a message.
321 lcd.backlight();
322 lcd.print("FluxDensity");
323 lcd.print(" (In Gauss):");
324
325 // Turn off the back light
326 backLightOff();
327
328 // Turn on the back light
329 backLight();
330
331 // Turn on the backlight and read a message.
332 lcd.backlight();
333 lcd.print("FluxDensity");
334 lcd.print(" (In Gauss):");
335
336 // Turn off the back light
337 backLightOff();
338
339 // Turn on the back light
340 backLight();
341
342 // Turn on the backlight and read a message.
343 lcd.backlight();
344 lcd.print("FluxDensity");
345 lcd.print(" (In Gauss):");
346
347 // Turn off the back light
348 backLightOff();
349
350 // Turn on the back light
351 backLight();
352
353 // Turn on the backlight and read a message.
354 lcd.backlight();
355 lcd.print("FluxDensity");
356 lcd.print(" (In Gauss):");
357
358 // Turn off the back light
359 backLightOff();
360
361 // Turn on the back light
362 backLight();
363
364 // Turn on the backlight and read a message.
365 lcd.backlight();
366 lcd.print("FluxDensity");
367 lcd.print(" (In Gauss):");
368
369 // Turn off the back light
370 backLightOff();
371
372 // Turn on the back light
373 backLight();
374
375 // Turn on the backlight and read a message.
376 lcd.backlight();
377 lcd.print("FluxDensity");
378 lcd.print(" (In Gauss):");
379
380 // Turn off the back light
381 backLightOff();
382
383 // Turn on the back light
384 backLight();
385
386 // Turn on the backlight and read a message.
387 lcd.backlight();
388 lcd.print("FluxDensity");
389 lcd.print(" (In Gauss):");
390
391 // Turn off the back light
392 backLightOff();
393
394 // Turn on the back light
395 backLight();
396
397 // Turn on the backlight and read a message.
398 lcd.backlight();
399 lcd.print("FluxDensity");
400 lcd.print(" (In Gauss):");
401
402 // Turn off the back light
403 backLightOff();
404
405 // Turn on the back light
406 backLight();
407
408 // Turn on the backlight and read a message.
409 lcd.backlight();
410 lcd.print("FluxDensity");
411 lcd.print(" (In Gauss):");
412
413 // Turn off the back light
414 backLightOff();
415
416 // Turn on the back light
417 backLight();
418
419 // Turn on the backlight and read a message.
420 lcd.backlight();
421 lcd.print("FluxDensity");
422 lcd.print(" (In Gauss):");
423
424 // Turn off the back light
425 backLightOff();
426
427 // Turn on the back light
428 backLight();
429
430 // Turn on the backlight and read a message.
431 lcd.backlight();
432 lcd.print("FluxDensity");
433 lcd.print(" (In Gauss):");
434
435 // Turn off the back light
436 backLightOff();
437
438 // Turn on the back light
439 backLight();
440
441 // Turn on the backlight and read a message.
442 lcd.backlight();
443 lcd.print("FluxDensity");
444 lcd.print(" (In Gauss):");
445
446 // Turn off the back light
447 backLightOff();
448
449 // Turn on the back light
450 backLight();
451
452 // Turn on the backlight and read a message.
453 lcd.backlight();
454 lcd.print("FluxDensity");
455 lcd.print(" (In Gauss):");
456
457 // Turn off the back light
458 backLightOff();
459
460 // Turn on the back light
461 backLight();
462
463 // Turn on the backlight and read a message.
464 lcd.backlight();
465 lcd.print("FluxDensity");
466 lcd.print(" (In Gauss):");
467
468 // Turn off the back light
469 backLightOff();
470
471 // Turn on the back light
472 backLight();
473
474 // Turn on the backlight and read a message.
475 lcd.backlight();
476 lcd.print("FluxDensity");
477 lcd.print(" (In Gauss):");
478
479 // Turn off the back light
480 backLightOff();
481
482 // Turn on the back light
483 backLight();
484
485 // Turn on the backlight and read a message.
486 lcd.backlight();
487 lcd.print("FluxDensity");
488 lcd.print(" (In Gauss):");
489
490 // Turn off the back light
491 backLightOff();
492
493 // Turn on the back light
494 backLight();
495
496 // Turn on the backlight and read a message.
497 lcd.backlight();
498 lcd.print("FluxDensity");
499 lcd.print(" (In Gauss):");
500
501 // Turn off the back light
502 backLightOff();
503
504 // Turn on the back light
505 backLight();
506
507 // Turn on the backlight and read a message.
508 lcd.backlight();
509 lcd.print("FluxDensity");
510 lcd.print(" (In Gauss):");
511
512 // Turn off the back light
513 backLightOff();
514
515 // Turn on the back light
516 backLight();
517
518 // Turn on the backlight and read a message.
519 lcd.backlight();
520 lcd.print("FluxDensity");
521 lcd.print(" (In Gauss):");
522
523 // Turn off the back light
524 backLightOff();
525
526 // Turn on the back light
527 backLight();
528
529 // Turn on the backlight and read a message.
530 lcd.backlight();
531 lcd.print("FluxDensity");
532 lcd.print(" (In Gauss):");
533
534 // Turn off the back light
535 backLightOff();
536
537 // Turn on the back light
538 backLight();
539
540 // Turn on the backlight and read a message.
541 lcd.backlight();
542 lcd.print("FluxDensity");
543 lcd.print(" (In Gauss):");
544
545 // Turn off the back light
546 backLightOff();
547
548 // Turn on the back light
549 backLight();
550
551 // Turn on the backlight and read a message.
552 lcd.backlight();
553 lcd.print("FluxDensity");
554 lcd.print(" (In Gauss):");
555
556 // Turn off the back light
557 backLightOff();
558
559 // Turn on the back light
560 backLight();
561
562 // Turn on the backlight and read a message.
563 lcd.backlight();
564 lcd.print("FluxDensity");
565 lcd.print(" (In Gauss):");
566
567 // Turn off the back light
568 backLightOff();
569
570 // Turn on the back light
571 backLight();
572
573 // Turn on the backlight and read a message.
574 lcd.backlight();
575 lcd.print("FluxDensity");
576 lcd.print(" (In Gauss):");
577
578 // Turn off the back light
579 backLightOff();
580
581 // Turn on the back light
582 backLight();
583
584 // Turn on the backlight and read a message.
585 lcd.backlight();
586 lcd.print("FluxDensity");
587 lcd.print(" (In Gauss):");
588
589 // Turn off the back light
590 backLightOff();
591
592 // Turn on the back light
593 backLight();
594
595 // Turn on the backlight and read a message.
596 lcd.backlight();
597 lcd.print("FluxDensity");
598 lcd.print(" (In Gauss):");
599
600 // Turn off the back light
601 backLightOff();
602
603 // Turn on the back light
604 backLight();
605
606 // Turn on the backlight and read a message.
607 lcd.backlight();
608 lcd.print("FluxDensity");
609 lcd.print(" (In Gauss):");
610
611 // Turn off the back light
612 backLightOff();
613
614 // Turn on the back light
615 backLight();
616
617 // Turn on the backlight and read a message.
618 lcd.backlight();
619 lcd.print("FluxDensity");
620 lcd.print(" (In Gauss):");
621
622 // Turn off the back light
623 backLightOff();
624
625 // Turn on the back light
626 backLight();
627
628 // Turn on the backlight and read a message.
629 lcd.backlight();
630 lcd.print("FluxDensity");
631 lcd.print(" (In Gauss):");
632
633 // Turn off the back light
634 backLightOff();
635
636 // Turn on the back light
637 backLight();
638
639 // Turn on the backlight and read a message.
640 lcd.backlight();
641 lcd.print("FluxDensity");
642 lcd.print(" (In Gauss):");
643
644 // Turn off the back light
645 backLightOff();
646
647 // Turn on the back light
648 backLight();
649
650 // Turn on the backlight and read a message.
651 lcd.backlight();
652 lcd.print("FluxDensity");
653 lcd.print(" (In Gauss):");
654
655 // Turn off the back light
656 backLightOff();
657
658 // Turn on the back light
659 backLight();
660
661 // Turn on the backlight and read a message.
662 lcd.backlight();
663 lcd.print("FluxDensity");
664 lcd.print(" (In Gauss):");
665
666 // Turn off the back light
667 backLightOff();
668
669 // Turn on the back light
670 backLight();
671
672 // Turn on the backlight and read a message.
673 lcd.backlight();
674 lcd.print("FluxDensity");
675 lcd.print(" (In Gauss):");
676
677 // Turn off the back light
678 backLightOff();
679
680 // Turn on the back light
681 backLight();
682
683 // Turn on the backlight and read a message.
684 lcd.backlight();
685 lcd.print("FluxDensity");
686 lcd.print(" (In Gauss):");
687
688 // Turn off the back light
689 backLightOff();
690
691 // Turn on the back light
692 backLight();
693
694 // Turn on the backlight and read a message.
695 lcd.backlight();
696 lcd.print("FluxDensity");
697 lcd.print(" (In Gauss):");
698
699 // Turn off the back light
700 backLightOff();
701
702 // Turn on the back light
703 backLight();
704
705 // Turn on the backlight and read a message.
706 lcd.backlight();
707 lcd.print("FluxDensity");
708 lcd.print(" (In Gauss):");
709
710 // Turn off the back light
711 backLightOff();
712
713 // Turn on the back light
714 backLight();
715
716 // Turn on the backlight and read a message.
717 lcd.backlight();
718 lcd.print("FluxDensity");
719 lcd.print(" (In Gauss):");
720
721 // Turn off the back light
722 backLightOff();
723
724 // Turn on the back light
725 backLight();
726
727 // Turn on the backlight and read a message.
728 lcd.backlight();
729 lcd.print("FluxDensity");
730 lcd.print(" (In Gauss):");
731
732 // Turn off the back light
733 backLightOff();
734
735 // Turn on the back light
736 backLight();
737
738 // Turn on the backlight and read a message.
739 lcd.backlight();
740 lcd.print("FluxDensity");
741 lcd.print(" (In Gauss):");
742
743 // Turn off the back light
744 backLightOff();
745
746 // Turn on the back light
747 backLight();
748
749 // Turn on the backlight and read a message.
750 lcd.backlight();
751 lcd.print("FluxDensity");
752 lcd.print(" (In Gauss):");
753
754 // Turn off the back light
755 backLightOff();
756
757 // Turn on the back light
758 backLight();
759
760 // Turn on the backlight and read a message.
761 lcd.backlight();
762 lcd.print("FluxDensity");
763 lcd.print(" (In Gauss):");
764
765 // Turn off the back light
766 backLightOff();
767
768 // Turn on the back light
769 backLight();
770
771 // Turn on the backlight and read a message.
772 lcd.backlight();
773 lcd.print("FluxDensity");
774 lcd.print(" (In Gauss):");
775
776 // Turn off the back light
777 backLightOff();
778
779 // Turn on the back light
780 backLight();
781
782 // Turn on the backlight and read a message.
783 lcd.backlight();
784 lcd.print("FluxDensity");
785 lcd.print(" (In Gauss):");
786
787 // Turn off the back light
788 backLightOff();
789
790 // Turn on the back light
791 backLight();
792
793 // Turn on the backlight and read a message.
794 lcd.backlight();
795 lcd.print("FluxDensity");
796 lcd.print(" (In Gauss):");
797
798 // Turn off the back light
799 backLightOff();
800
801 // Turn on the back light
802 backLight();
803
804 // Turn on the backlight and read a message.
805 lcd.backlight();
806 lcd.print("FluxDensity");
807 lcd.print(" (In Gauss):");
808
809 // Turn off the back light
810 backLightOff();
811
812 // Turn on the back light
813 backLight();
814
815 // Turn on the backlight and read a message.
816 lcd.backlight();
817 lcd.print("FluxDensity");
818 lcd.print(" (In Gauss):");
819
820 // Turn off the back light
821 backLightOff();
822
823 // Turn on the back light
824 backLight();
825
826 // Turn on the backlight and read a message.
827 lcd.backlight();
828 lcd.print("FluxDensity");
829 lcd.print(" (In Gauss):");
830
831 // Turn off the back light
832 backLightOff();
833
834 // Turn on the back light
835 backLight();
836
837 // Turn on the backlight and read a message.
838 lcd.backlight();
839 lcd.print("FluxDensity");
840 lcd.print(" (In Gauss):");
841
842 // Turn off the back light
843 backLightOff();
844
845 // Turn on the back light
846 backLight();
847
848 // Turn on the backlight and read a message.
849 lcd.backlight();
850 lcd.print("FluxDensity");
851 lcd.print(" (In Gauss):");
852
853 // Turn off the back light
854 backLightOff();
855
856 // Turn on the back light
857 backLight();
858
859 // Turn on the backlight and read a message.
860 lcd.backlight();
861 lcd.print("FluxDensity");
862 lcd.print(" (In Gauss):");
863
864 // Turn off the back light
865 backLightOff();
866
867 // Turn on the back light
868 backLight();
869
870 // Turn on the backlight and read a message.
871 lcd.backlight();
872 lcd.print("FluxDensity");
873 lcd.print(" (In Gauss):");
874
875 // Turn off the back light
876 backLightOff();
877
878 // Turn on the back light
879 backLight();
880
881 // Turn on the backlight and read a message.
882 lcd.backlight();
883 lcd.print("FluxDensity");
884 lcd.print(" (In Gauss):");
885
886 // Turn off the back light
887 backLightOff();
888
889 // Turn on the back light
890 backLight();
891
892 // Turn on the backlight and read a message.
893 lcd.backlight();
894 lcd.print("FluxDensity");
895 lcd.print(" (In Gauss):");
896
897 // Turn off the back light
898 backLightOff();
899
900 // Turn on the back light
901 backLight();
902
903 // Turn on the backlight and read a message.
904 lcd.backlight();
905 lcd.print("FluxDensity");
906 lcd.print(" (In Gauss):");
907
908 // Turn off the back light
909 backLightOff();
910
911 // Turn on the back light
912 backLight();
913
914 // Turn on the backlight and read a message.
915 lcd.backlight();
916 lcd.print("FluxDensity");
917 lcd.print(" (In Gauss):");
918
919 // Turn off the back light
920 backLightOff();
921
922 // Turn on the back light
923 backLight();
924
925 // Turn on the backlight and read a message.
926 lcd.backlight();
927 lcd.print("FluxDensity");
928 lcd.print(" (In Gauss):");
929
930 // Turn off the back light
931 backLightOff();
932
933 // Turn on the back light
934 backLight();
935
936 // Turn on the backlight and read a message.
937 lcd.backlight();
938 lcd.print("FluxDensity");
939 lcd.print(" (In Gauss):");
940
941 // Turn off the back light
942 backLightOff();
943
944 // Turn on the back light
945 backLight();
946
947 // Turn on the backlight and read a message.
948 lcd.backlight();
949 lcd.print("FluxDensity");
950 lcd.print(" (In Gauss):");
951
952 // Turn off the back light
953 backLightOff();
954
955 // Turn on the back light
956 backLight();
957
958 // Turn on the backlight and read a message.
959 lcd.backlight();
960 lcd.print("FluxDensity");
961 lcd.print(" (In Gauss):");
962
963 // Turn off the back light
964 backLightOff();
965
966 // Turn on the back light
967 backLight();
968
969 // Turn on the backlight and read a message.
970 lcd.backlight();
971 lcd.print("FluxDensity");
972 lcd.print(" (In Gauss):");
973
974 // Turn off the back light
975 backLightOff();
976
977 // Turn on the back light
978 backLight();
979
980 // Turn on the backlight and read a message.
981 lcd.backlight();
982 lcd.print("FluxDensity");
983 lcd.print(" (In Gauss):");
984
985 // Turn off the back light
986 backLightOff();
987
988 // Turn on the back light
989 backLight();
990
991 // Turn on the backlight and read a message.
992 lcd.backlight();
993 lcd.print("FluxDensity");
994 lcd.print(" (In Gauss):");
995
996 // Turn off the back light
997 backLightOff();
998
999 // Turn on the back light
1000 backLight();
1001
1002 // Turn on the backlight and read a message.
1003 lcd.backlight();
1004 lcd.print("FluxDensity");
1005 lcd.print(" (In Gauss):");
1006
1007 // Turn off the back light
1008 backLightOff();
1009
1010 // Turn on the back light
1011 backLight();
1012
1013 // Turn on the backlight and read a message.
1014 lcd.backlight();
1015 lcd.print("FluxDensity");
1016 lcd.print(" (In Gauss):");
1017
1018 // Turn off the back light
1019 backLightOff();
1020
1021 // Turn on the back light
1022 backLight();
1023
1024 // Turn on the backlight and read a message.
1025 lcd.backlight();
1026 lcd.print("FluxDensity");
1027 lcd.print(" (In Gauss):");
1028
1029 // Turn off the back light
1030 backLightOff();
1031
1032 // Turn on the back light
1033 backLight();
1034
1035 // Turn on the backlight and read a message.
1036 lcd.backlight();
1037 lcd.print("FluxDensity");
1038 lcd.print(" (In Gauss):");
1039
1040 // Turn off the back light
1041 backLightOff();
1042
1043 // Turn on the back light
1044 backLight();
1045
1046 // Turn on the backlight and read a message.
1047 lcd.backlight();
1048 lcd.print("FluxDensity");
1049 lcd.print(" (In Gauss):");
1050
1051 // Turn off the back light
1052 backLightOff();
1053
1054 // Turn on the back light
1055 backLight();
1056
1057 // Turn on the backlight and read a message.
1058 lcd.backlight();
1059 lcd.print("FluxDensity");
1060 lcd.print(" (In Gauss):");
1061
1062 // Turn off the back light
1063 backLightOff();
1064
1065 // Turn on the back light
1066 backLight();
1067
1068 // Turn on the backlight and read a message.
1069 lcd.backlight();
1070 lcd.print("FluxDensity");
1071 lcd.print(" (In Gauss):");
1072
1073 // Turn off the back light
1074 backLightOff();
1075
1076 // Turn on the back light
1077 backLight();
1078
1079 // Turn on the backlight and read a message.
1080 lcd.backlight();
1081 lcd.print("FluxDensity");
1082 lcd.print(" (In Gauss):");
1083
1084 // Turn off the back light
1085 backLightOff();
1086
1087 // Turn on the back light
1088 backLight();
1089
1090 // Turn on the backlight and read a message.
1091 lcd.backlight();
1092 lcd.print("FluxDensity");
1093 lcd.print(" (In Gauss):");
1094
1095 // Turn off the back light
1096 backLightOff();
1097
1098 // Turn on the back light
1099 backLight();
1100
1101 // Turn on the backlight and read a message.
1102 lcd.backlight();
1103 lcd.print("FluxDensity");
1104 lcd.print(" (In Gauss):");
1105
1106 // Turn off the back light
1107 backLightOff();
1108
1109 // Turn on the back light
1110 backLight();
1111
1112 // Turn on the backlight and read a message.
1113 lcd.backlight();
1114 lcd.print("FluxDensity");
1115 lcd.print(" (In Gauss):");
1116
1117 // Turn off the back light
1118 backLightOff();
1119
1120 // Turn on the back light
1121 backLight();
1122
1123 // Turn on the backlight and read a message.
1124 lcd.backlight();
1125 lcd.print("FluxDensity");
1126 lcd.print(" (In Gauss):");
1127
1128 // Turn off the back light
1129 backLightOff();
1130
1131 // Turn on the back light
1132 backLight();
1133
1134 // Turn on the backlight and read a message.
1135 lcd.backlight();
1136 lcd.print("FluxDensity");
1137 lcd.print(" (In Gauss):");
1138
1139 // Turn off the back light
1140 backLightOff();
1141
1142 // Turn on the back light
1143 backLight();
1144
1145 // Turn on the backlight and read a message.
1146 lcd.backlight();
1147 lcd.print("FluxDensity");
1148 lcd.print(" (In Gauss):");
1149
1150 // Turn off the back light
1151 backLightOff();
1152
1153 // Turn on the back light
1154 backLight();
1155
1156 // Turn on the backlight and read a message.
1157 lcd.backlight();
1158 lcd.print("FluxDensity");
1159 lcd.print(" (In Gauss):");
1160
1161 // Turn off the back light
1162 backLightOff();
1163
1164 // Turn on the back light
1165 backLight();
1166
1167 // Turn on the backlight and read a message.
1168 lcd.backlight();
1169 lcd.print("FluxDensity");
1170 lcd.print(" (In Gauss):");
1171
1172 // Turn off the back light
1173 backLightOff();
1174
1175 // Turn on the back light
1176 backLight();
1177
1178 // Turn on the backlight and read a message.
1179 lcd.backlight();
1180 lcd.print("FluxDensity");
1181 lcd.print(" (In Gauss):");
1182
1183 // Turn off the back light
1184 backLightOff();
1185
1186 // Turn on the back light
1187 backLight();
1188
1189 // Turn on the backlight and read a message.
1190 lcd.backlight();
1191 lcd.print("FluxDensity");
1192 lcd.print(" (In Gauss):");
1193
1194 // Turn off the back light
1195 backLightOff();
1196
1197 // Turn on the back light
1198 backLight();
1199
1200 // Turn on the backlight and read a message.
1201 lcd.backlight();
1202 lcd.print("FluxDensity");
1203 lcd.print(" (In Gauss):");
1204
1205 // Turn off the back light
1206 backLightOff();
1207
1208 // Turn on the back light
1209 backLight();
1210
1211 // Turn on the backlight and read a message.
1212 lcd.backlight();
1213 lcd.print("FluxDensity");
1214 lcd.print(" (In Gauss):");
1215
1216 // Turn off the back light
1217 backLightOff();
1218
1219 // Turn on the back light
1220 backLight();
1221
1222 // Turn on the backlight and read a message.
1223 lcd.backlight();
1224 lcd.print("FluxDensity");
1225 lcd.print(" (In Gauss):");
1226
1227 // Turn off the back light
1228 backLightOff();
1229
1230 // Turn on the back light
1231 backLight();
1232
1233 // Turn on the backlight and read a message.
1234 lcd.backlight();
1235 lcd.print("FluxDensity");
1236 lcd.print(" (In Gauss):");
1237
1238 // Turn off the back light
1239 backLightOff();
1240
1241 // Turn on the back light
1242 backLight();
1243
1244 // Turn on the backlight and read a message.
1245 lcd.backlight();
1246 lcd.print("FluxDensity");
1247 lcd.print(" (In Gauss):");
1248
1249 // Turn off the back light
1250 backLightOff();
1251
1252 // Turn on the back light
1253 backLight();
1254
1255 // Turn on the backlight and read a message.
1256 lcd.backlight();
1257 lcd.print("FluxDensity");
1258 lcd.print(" (In Gauss):");
1259
1260 // Turn off the back light
12
```

$$\text{Average } (\bar{x}) = \frac{\text{Sum of Readings}}{\text{No. of Readings}}$$

$$\text{Standard deviation } (\sigma) = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}}$$

Table 1: Averages and Standard deviations of the Output Voltages

Input Magnetic Field (Gauss)	Average Output Voltage (V)	Standard deviation (V)
-520.0	1.141	0.079
-280.4	1.785	0.077
-100.1	2.231	0.003
-33.7	2.434	0.040
0.0	2.506	0.021
33.7	2.615	0.056
100.1	2.826	0.082
280.4	3.309	0.085
520.0	3.915	0.016

Table 1 shows the average output voltage and its deviation from the average value considering the given input magnetic field for the sensor using the readings obtained from *Table 2*. These values are calculated using the two equations given above.

D. The Sensor Module

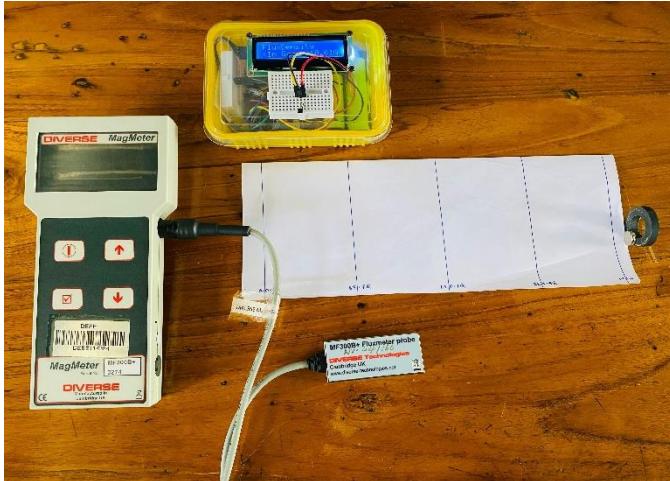


Figure 5: Calibration Setup

Figure 5 shows the calibration setup that was used for calibrating our sensor. We used a magnetic fluxmeter and a permanent magnet for this setup. The permanent magnet was placed at a fixed position and the strength of the magnetic field was measured at different positions on a white paper using the fluxmeter up to a resolution of 0.1 Gauss. Then, the measured values were marked on those positions to obtain known input magnetic fields for the sensor. Once the setup was done, we

kept the sensor at those marked positions and measured the output voltage produced by the sensor using Arduino. By changing the side of the permanent magnet, negative magnetic field values were also obtained. For the calibration to be complete, we took 5 sets of such readings at five different times as shown in *Table 2*.

The sensor module is powered by a 5 V DC battery and the SS49E, the sensing element is isolated from the battery, and wires using the yellow-colored compartment as shown in *Figure 5*. This isolation is done to avoid interferences and variations in the displayed output.

IV. RESULTS

A. Observations

Table 2: Variation Output Voltage with Input Magnetic Field

Input (Gauss)	Output Voltage Variation (V)				
	Set 1	Set 2	Set 3	Set 4	Set 5
-520.0	1.123	1.296	1.088	1.113	1.085
-280.4	1.743	1.750	1.939	1.742	1.748
-100.1	2.235	2.229	2.225	2.231	2.232
-33.7	2.410	2.421	2.425	2.511	2.399
0.0	2.486	2.523	2.532	2.476	2.510
33.7	2.602	2.582	2.591	2.572	2.724
100.1	2.825	2.753	2.773	2.982	2.795
280.4	3.245	3.257	3.321	3.249	3.469
520.0	3.912	3.904	3.945	3.901	3.913

Table 2 shows five sets of readings that we took from the calibration setup, *Figure 5*. These readings were used to draw the calibration curve (input-output characteristic) and calculate the sensitivity of the sensor module.

B. Input-output characteristic curve

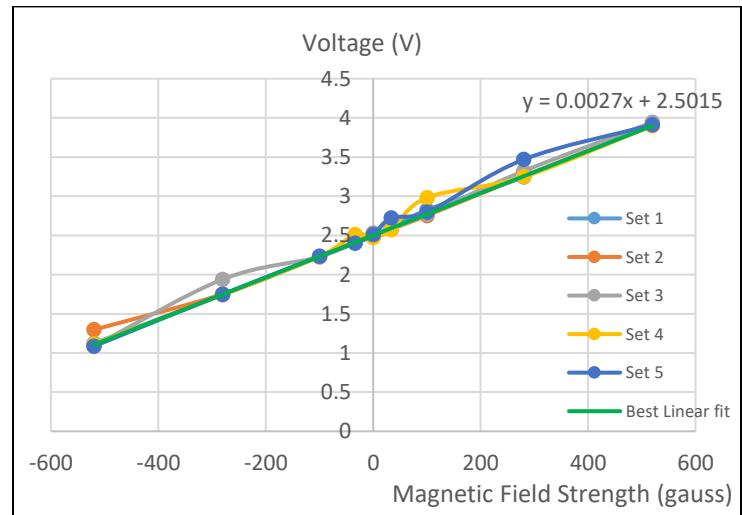


Figure 6: Variation of Output Voltage with Input Magnetic Field

Figure 6 depicts the curves drawn from the data in *Table 2* and the best linear fit curve drawn from the 5 curves is shown using the green color. The characteristics of this best linear fit curve can be used to analyze the results of the calibration process further.

$$y = 0.0027x + 2.5015$$

Therefore, the gradient of the best linear fit curve is 2.7 mV/G, and the intercept is 2.5015 V. The gradient acts as the sensitivity of the sensor and intercept acts as an offset error to the sensor. We know that 2.5 V corresponds to the 0 Gauss state. Thus, the offset error would be 1.5 mV in positive direction.

$$\text{Sensitivity} = 2.7 \text{ mV/Gauss}$$

$$\begin{aligned} \text{Offset Error in Gauss} &= \frac{1.5}{2.7} G \\ &= 0.55 \text{ Gauss} \end{aligned}$$

This value of 0.55 Gauss was always appearing on the LCD at every location even though a magnetic field was not applied.

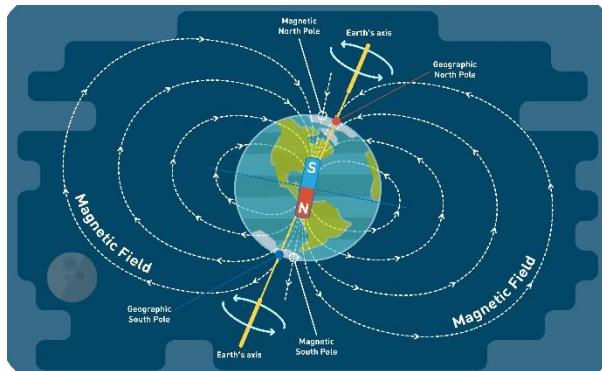


Figure 7: Earth's Magnetic Field Lines (Source: Dobrijevic, 2022: online)

Figure 7 shows the distribution of magnetic field lines due to the presence of a magnet inside Earth's core. They are parallel to the earth and on the surface of the earth, it is like a constant. According to research, the value is found to be in the range of 0.22 Gauss to 0.67 Gauss. (British Geological Survey, n.d.) Hence, it is notable that the offset error also lies in this range. Therefore, a conclusion can be made that this offset error is the Earth's magnetic field.

V. DISCUSSION

A. Difficulties

1) *Method Selection:* Several methods were proposed for developing the sensor. However, it was required to select only one method. It was a bit of a challenge to select the most suitable method. For that, several factors like cost, easiness of implementation, and simplicity of the setup were considered.

By comparing these factors, we decided to follow the method of Arduino microcontrollers.

2) *Lower resolution of the sensor to measure PFMF:* the magnetic field strength on the Earth's surface caused by the current flow in high tension lines can be calculated using the equation,

$$B = \frac{\mu I}{2\pi r}$$

B – magnetic field strength

μ – permeability of the medium

I – current flow in the conductor

r – distance from the conductor to the point under consideration. (Charles A. Bishop, 2011)

Consider that a current of 100 A flows through the high-tension line. Then, the magnetic field strength below 8 m would be 0.0257 Gauss. However, the resolution of the sensor is 0.01 Gauss. So, 0.0057 part can not be detected from this sensor module. For that, the option was to decrease the range of measurement and improve the sensitivity by using an amplifier circuit to amplify the voltage so that the resolution can be improved. Also, it is possible to implement two SS49E into the circuit so that the average of two values can be taken to improve the resolution.

3) *Earth's magnetic field is much higher than the value due to PFMFs:* Earth's magnetic field is in the range of 220 mG to 670 mG. But PFMFs are in the range of 0 to 100 mG. Therefore, this value is slightly smaller. Always, the Earth's magnetic field is parallel to the Earth's surface and the sensor only detects magnetic fields coming perpendicular to it, *Figure 3*. So, by keeping the sensor module parallel to the Earth, the effect of the Earth's magnetic field can be avoided.

4) *Interference and Noise:* Magnetic fields can be influenced by various external factors, including nearby electronic devices, power sources, and other magnetic materials. Filtering out unwanted noise and minimizing interference from these sources is crucial for obtaining reliable and accurate measurements. So, it is possible to shield the sensor from external electromagnetic interference using magnetic field shielding materials like steel. Also, several filtering techniques, such as analog or digital filters, to suppress noise and unwanted signals can be implemented.

5) *Power Consumption:* A lot of power is required for the operation of microcontrollers. Also, it is not reliable to change batteries every time. So, advanced semiconductor technologies, such as low-power microcontrollers, and integrated sensor solutions can be utilized to reduce overall power consumption. Furthermore, a thought can be made to run the sensor using solar power which can be done in future developments.

6) *Sensor to be used in several environmental conditions:* Magnetic field sensors may be deployed in diverse environmental conditions, including outdoor or harsh industrial environments. Ensuring robustness and reliability under varying temperatures, humidity levels, and exposure to dust or moisture requires adequate protection and packaging of the sensor components. For that, the sensor components can be sealed with protective coatings. Also, it is important to conduct extensive

environmental testing to validate sensor performance under various conditions, including temperature, humidity, and mechanical stress.

B. Strengths

1) *High sensitivity:* Hall effect sensors are known for their high sensitivity to magnetic fields, enabling accurate detection of even subtle changes in field intensity. This high sensitivity allows for precise measurement of magnetic fields across a wide range of intensities.

2) *Linear response:* Hall effect sensors typically provide a linear response to changes in magnetic field strength, making it easier to calibrate and interpret the sensor's output. This linearity simplifies the conversion of voltage readings into meaningful units, such as Gauss, facilitating accurate measurement.

3) *Real-time processing:* By interfacing the Hall effect sensor with an Arduino microcontroller, real-time processing and analysis of magnetic field data become feasible. The Arduino can quickly convert analog voltage signals from the sensor into digital data, enabling rapid processing and display of magnetic field measurements.

4) *Integration with display interfaces:* Arduino microcontrollers can easily interface with various display interfaces, such as LCD screens or LEDs, to provide real-time visualization of magnetic field measurements. This capability enhances the usability and accessibility of the sensor system, enabling users to monitor magnetic field levels conveniently.

5) *Low Cost:* Hall effect sensors and Arduino microcontrollers are relatively inexpensive components, making the overall sensor system cost-effective, especially for educational or research purposes.

C. Weaknesses

1) *Limited Resolution:* Hall effect sensors have limited resolution, particularly in low magnetic field intensity ranges. This limitation can result in reduced accuracy when detecting small changes in magnetic field strength, especially in applications requiring high precision.

2) *Temperature Sensitivity:* Hall effect sensors are slightly sensitive to temperature variations, leading to fluctuations in their output readings. Without proper temperature compensation techniques, this sensitivity can introduce errors in magnetic field measurements, particularly in environments with wide temperature fluctuations.

3) *Interference and noise:* Hall effect sensors and Arduino microcontrollers are susceptible to electromagnetic interference (EMI) and electrical noise from nearby sources, such as motors, power sources, or electronic devices. Without adequate shielding or noise mitigation measures, these external disturbances can degrade the accuracy and reliability of magnetic field measurements.

D. Comparison

The module developed using a Hall sensor with an Arduino microcontroller offers a cost-effective and portable solution for

measuring power frequency magnetic fields. While not matching the precision of high-end magnetometers like fluxgate or SQUID magnetometers, it provides sufficient sensitivity and accuracy for many applications. Its compact size, ease of integration, and real-time monitoring capabilities make it ideal for handheld or embedded use, while its affordability and user-friendly interface make it accessible to a wide range of users. Although it may have slightly lower sampling rates and robustness compared to some magnetometers, proper calibration, and shielding can mitigate environmental influences, making it a practical choice for educational projects, field monitoring, and basic research endeavors.

VI. CONCLUSION

In conclusion, the development of our remote power-frequency magnetic field sensor marks a significant advancement in environmental monitoring and human safety. Integrating a linear Hall effect sensor with an Arduino microcontroller has enabled precise detection and measurement of magnetic field levels. Calibration revealed an offset error attributed to the Earth's magnetic field, underscoring the importance of continuous testing procedures in sensor development. Additionally, the sensor's bipolarity allows for measuring both positive and negative magnetic fields, enhancing its versatility in real-world applications.

The significance of this sensor extends to its potential impact on human health and environmental protection. By providing early warnings when magnetic field strengths exceed safe limits, especially near power stations and grid stations, the sensor serves as a proactive safeguard against potential health risks. Furthermore, its isolation using proper magnetic field shields ensures accurate measurements and minimizes interference from external sources, enhancing its reliability in practical settings.

Looking forward, the sensor's adaptability opens doors to diverse applications, from integrating user alerts via SMS or GUI interfaces to automated systems for controlling equipment based on magnetic field measurements. Its suitability for industries, laboratories, homes, and agricultural settings emphasizes its role in resource conservation and human well-being. In essence, the development of this sensor reflects our commitment to innovation and societal progress, paving the way for a safer and more sustainable future.

VII. ACKNOWLEDGEMENT

We express our heartfelt gratitude to the course coordinators of the subject, Dr. Ruwan Ranaweera, Dr. Nalin Harischandra, and Dr. Tharindu Weerakoon, for their invaluable guidance and support throughout this project. Special appreciation is extended to our advisor, Prof. Manjula Fernando, whose experience and encouragement were instrumental in the

success of this attempt. We also extend our sincere thanks to our senior students and batchmates for their unwavering support and fellowship. Also, any errors or omissions in this report remain our responsibility and should not be reflected upon the respected individuals mentioned above.

VIII. REFERENCES

- [1] British Geological Survey, n.d. An Overview of the Earth's Magnetic Field [WWW Document]. URL <http://www.geomag.bgs.ac.uk/education/earthmag.html> (accessed 2.29.24).
- [2] Charles A. Bishop, 2011. Magnetic Field Strength - an overview [WWW Document]. URL <https://www.sciencedirect.com/topics/engineering/magnetic-field-strength> (accessed 3.1.24).
- [3] Dilip Raja, 2015. Magnetic Field Strength Measurement using Arduino [WWW Document]. URL <https://circuitdigest.com/microcontroller-projects/arduino-magnetic-field-measurement> (accessed 2.29.24).
- [4] Hareendran, T.K., 2019. SS49E Hall-Effect Sensor & A Random Hack. Codrey Electron. URL <https://www.codrey.com/electronic-circuits/ss49e-hall-effect-sensor-a-random-hack/> (accessed 3.2.24).
- [5] Maalej, N., 2011. External and internal electromagnetic exposures of workers near high voltage power lines. Prog. Electromagn. Res. C 19. <https://doi.org/10.2528/PIERC10110601>
- [6] SS49E datasheet: A Versatile Hall-Effect Sensor, 2022. Free Online PCB CAD Libr. URL <https://www.ultralibrarian.com/2022/04/26/ss49e-datasheet-a-versatile-hall-effect-sensor-ulc> (accessed 3.2.24).