EE3810 Lab 8 – Magnetic (Hall Effect) Proximity Sensor

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1. Concepts

- Hall effect
- Hall effect sensor
- magnetic field
- window comparator
- voltage divider
- LED

2. Objectives

This lab demonstrates the implementation of a Hall Effect sensor and a window comparator circuit.

In completing this lab, you will:

a. Learn how to use the Hall effect sensor
b. Set up a three level window comparator to create an informative LED indicator display
c. Gain more experience bread boarding circuits

3. Background Theory

<u>A Biomedical Application: Placement of a Deep Brain Stimulation Electrode</u>

One of the key factors in the success of deep brain stimulation for any given patient is precise placement of the electrode in the appropriate location of the brain to target disease symptoms. Neurosurgeons position the electrodes with respect to coordinates on a stereotaxic frame. The depth of the electrode is controlled with a microdrive. To confirm how far the electrode has been advanced, a proximity sensor like the Hall effect sensor could be used.

<u>Hall Effect Sensor</u>

When a conductive material has an electrical current running through it, and a magnetic field applied perpendicular to the current, a charge will build as force is exerted upon electrons to congregate in a vector (in the conductive material) perpendicular to both the magnetic field and electrical current (see figure 1). The magnetic field right hand rule from physics may remind you of these vectors. This phenomenon was discovered by Edwin Hall in 1879 and has been aptly called the Hall Effect. The congregating electrons create a charge differential which can be measured as a voltage potential (V_{hall}). Indirectly, the strength and polarity of the magnetic field can be determined by this voltage potential if the dimensions, conductivity, quantity of charge available, and the amount of electrical current flowing through the material are known.

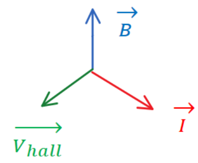

Figure 1 – Magnetic Field Vectors

It has been found that semiconductors can also exhibit the Hall Effect, and hence micro-electronic magnetic field sensors called Hall Effect Sensors have been developed. Many of these integrated circuits contain support hardware (e.g.: current sources, amplifiers, logic circuitry) to ease adaptation into projects.

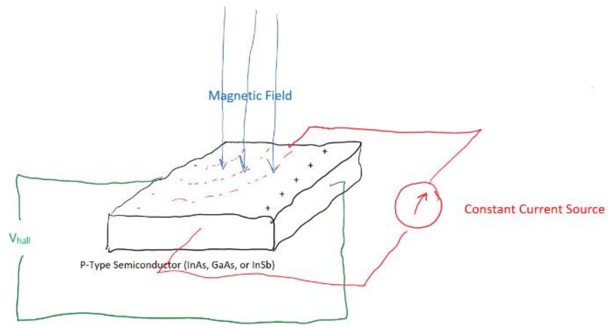

Figure 2 – Simplified Diagram of Hall Effect Sensor

The Hall Effect sensor used in this lab (SS49E) is a three pin device that uses two of the pins for power (2.7-6.5Vdc), and one for output. The output is nominally around 2.5Vdc when a magnetic field is absent. In the presence of a nearby magnetic field it will increase or decrease its output voltage from nominal based on the polarity and strength of the magnetic field encountered.

<u>Window Comparator</u>

By utilizing two or more comparators a circuit that is known as a window comparator can be implemented. This is a circuit that reacts when an input voltage falls into a preset range. The range is set by [a] simple voltage divider[s].

In this lab we use three comparators to implement a three level led meter (i.e.: window comparator). This level meter is sensitive to three voltage levels that are set by a three resistor voltage divider. The input to the level meter is connected to the output of the Hall Effect sensor. When the sensor is not in the presence of a strong magnetic field, the nominal output voltage (~2.5VDC) falls within the middle level of the window comparator and the center LED is illuminated. A strong magnetic field will cause the sensor's output to rise or fall from nominal (depending on the magnetic pole being presented) and will light up one of the other two LEDs.

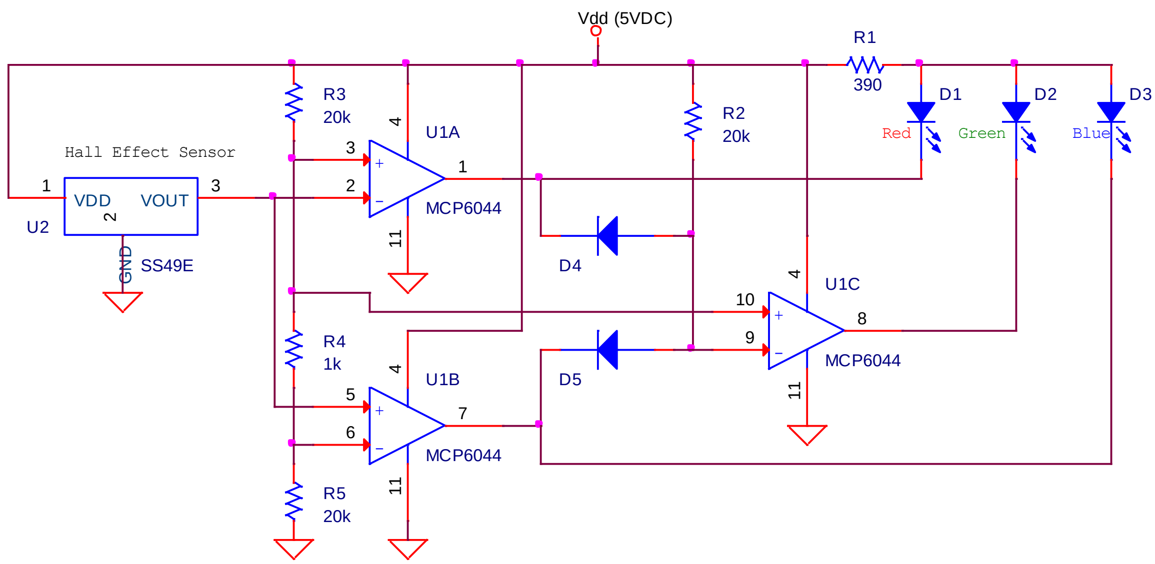

Figure 3 – Schematic Diagram of Window Comparator with Hall Effect Sensor Input

4. Pre-lab

1. Sketch a block diagram showing how the feedback-controlled drive for the DBS electrode placement could be configured using a Hall effect sensor.
2. Determine under what conditions the red LED will turn on? Green LED? Blue LED?

5. Procedure

5.1 Components Required

Component	Quantity	Description
U1	1	MCP6044 Quad Op-Amp
U2	1	SS49E Hall Effect Sensor
D1, D2, D3	1 Each	LEDs (red, green, blue; respectively)
D4, D5	2	1N914 or 1N4001 small signal rectifiers (diodes), or equivalent
R1	1	390 ohm resistor
R2, R3, R5	4	20K ohm resistors, with one extra for Step 4.3.7
R4	1	1K ohm resistor
Magnet	1	small magnet

Test Equipment: 5V DC power supply, multimeter, breadboard with jumper wires, test leads, etc.
Datasheets for U1 & U2

5.2 Hall Effect Sensor

1. Place the Hall Effect sensor in your breadboard and connect a 5VDC power supply to it (see datasheet for correct pin-out).
2. Connect a voltmeter across the output pin of U2 and the power supply ground.

3. Write down the output voltage of U2.
4. Now place a magnet very near U2, observe and record the output voltage of U2.
5. Turn the magnet around 180°, observe and record the output voltage of U2.
6. Remove the magnet from the vicinity of U2, observe and record the output voltage of U2.

5.3 Window Comparator

1. Construct the circuit portrayed in the schematic diagram, Figure 3, except do not yet connect U2 to the rest of the circuit.
2. After carefully double-checking your circuit, apply 5VDC between Vdd and ground.
3. Does anything happen, if so, what?
4. Use a DC power supply to apply a test voltage in place of VOUT. Slowly vary the voltage from 0 to 5VDD and record your observations.
5. Now, connect U2 (VOUT) to the rest of the circuit. Place a magnet near U2. What happens, and why?
6. Turn the magnet around 180°. What happens, and why?
7. Take the magnet away from U2. What happens, and why?
8. Replace R4 with a 20K ohm resistor. Repeat steps 4-6. What is different this time?

6. Questions

1. Explain how a Hall Effect Sensor works. What happens inside the sensor when you reverse your activating magnet 180°? Why?
2. Using the schematic in Figure 3 as a reference, calculate the theoretical voltages at pins 3, 6, and 10 of U1. Now substitute a 20K ohm resistor in place of R4. Recalculate the theoretical voltages at pins 3, 6, and 10 of U1.
3. Explain the purpose of D4 and D5 in the schematic of Figure 3.
4. What other biomedical applications might a Hall effect sensor be useful for?