Lab 8: SAMPLE DETECTION (MAGNETIC SENSORS AND COLOR SENSORS)

1. Introduction

In this lab, students will learn how to use sensors necessary for detecting samples in your project. This is focused on using the Hall effect sensor to detect magnetic fields and a colored LED and phototransistor to detect colors. The lab focuses on circuitry necessary to effectively use both sensors. The lab investigates how distance, orientation, and movement effect readings from the hall effect sensor. Techniques for using the color sensor are also investigated, including methods for calibrating the sensor.

1.1 Lab Objectives

- Understand and use Hall effect sensors
- Understand the effect of:
    - Orientation
    - Distance
    - Relative motion
- Understand the use of color sensors

1.2 Project Objectives

- Implement a magnetic sensing method
- Locate a magnetic source
- Implement a color sensing method
- Detect a color of a sample

1.3 Lab Hardware

- Allegro A1324LUA-T Hall Effect Sensor
- MCP6004 op-amp
- Jumper wire kit
- Solderless breadboard
- Color Sensor Circuit

1.4 Project Hardware

- Allegro A1324LUA-T Hall Effect Sensor
- MCP6004 op-amp
- RGB LED and 330 Ω pull up resistor
- Photo Transistor and 10 kΩ pull down resistor

2. Laboratory Concepts

2.1 Magnetic fields

Magnetic fields permeate the space surrounding a magnet as illustrated in Figure 1. Lines of magnetic flux flow from the north pole of a magnet to the south pole. Electric current flowing through a conductor also generates magnetic flux.

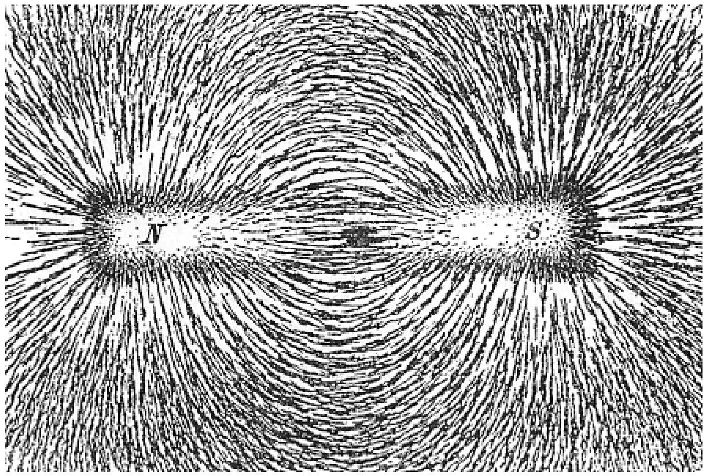


Figure 1. Magnet field of a bar magnet. Public domain image: Magnet0873.png.

The magnetic field surrounding a single conducting wire is very weak. If, however, the conductor is formed into a coil, the lines of flux are concentrated and the strength increases, as illustrated in Figure 2.

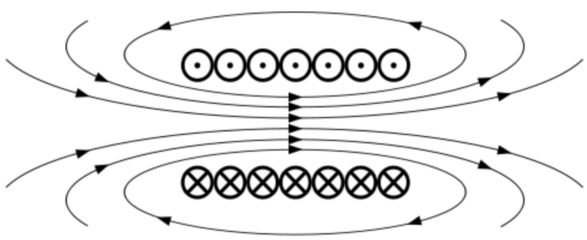


Figure 2. Solenoid coil field lines. Public domain image: solenoid.svg.

Electric and magnetic fields can exert forces on each other. The magnitude and direction of the magnetic force generated on an electrically charged particle is found using the Lorentz force equation is:

$$\vec{F}_{magnetic} = q\vec{v} \times \vec{B} \quad (1)$$

where $\vec{F}_{magnetic}$ is the force vector, q is the charge in coulombs, $\vec{v}$ is the velocity vector of the charge, and $\vec{B}$ is the magnetic field vector. Because the force is the result of a cross product, it is perpendicular to both the direction of the charged particle's motion and the magnetic field, as illustrated in the following figure.

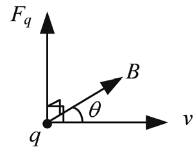


Figure 3. Force, F_q on a charged particle, q, moving in a magnetic field, B, with velocity, v.

In the case of a DC motor, electrons flow through an armature that is wound such that the current is principally parallel to the shaft. Permanent magnets are placed such that their field is directed perpendicular to the shaft. This arrangement results in a force on the armature creating a net torque that makes the shaft spin. This arrangement is illustrated in the figure below.

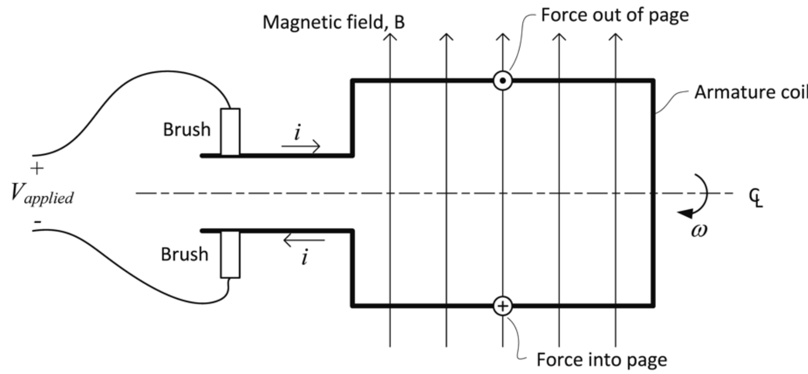


Figure 4. Diagram of a DC motor armature in a magnetic field, B.

The SI units for the strength of a magnetic field can be deduced from (1), with the force in Newtons (N), the charge in Coulombs (C), and the velocity in meters per second (m/s). Therefore, the units of the magnetic field are Newton seconds per Coulomb meter (N s/C m), called a Tesla (T). A Tesla is an enormous quantity when compared to typical magnetic fields, so the Gauss (G) is commonly used. One Gauss is equivalent to 1/10,000 Teslas. For comparison, the earth's magnetic field has a strength of about 0.5 Gauss and some of the most powerful man-made permanent magnets have a field strength of about 14 Tesla.

2.2 Sensing Magnetic fields

Magnetic fields cannot be detected directly; but, their effect can be measured through their interaction with materials and electricity. There are many devices that can be used to detect the presence of magnetic fields. These include, but are not limited to: reed switches, induction coils, flux gates, magnetotransistors, magnetodiodes, giant magnetoresistive elements (GMRs), anisotropic magnetoresistive (AMR) sensors, and Hall effect sensors. Many of these are at the cutting edge of magnetic sensing technology and are, consequently, very expensive. In this lab, the discussion of magnetic sensors will be limited to reed switches and Hall effect sensors since they are both readily available and affordable.

Reed Switches

Reed switches are constructed as with two separate iron reeds suspended in a glass tube as illustrated in Figure 5 (left). As a magnetic field is brought near a reed switch the leaves become magnetized, each end developing a north and south pole, as illustrated in Figure 5 (right). When the attractive force between the reeds overcomes their stiffness, they touch and current is permitted to flow through the switch. In this way, they act as a magnetically activated switch.

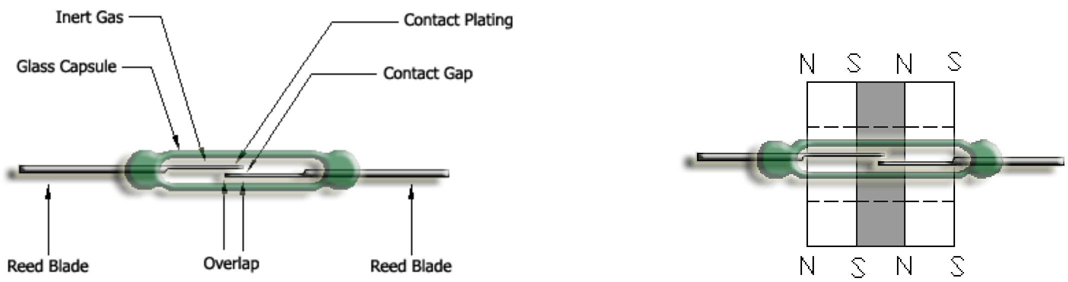


Figure 5. Reed switch illustration.

Reed switches are useful as a digital (on/off) senor to the presence of a magnetic field, and make good proximity sensors. However, it is not easy to predict the distance from a magnetic source at which they will engage, which will also depend on the orientation of the sensor relative to the magnetic field. Additionally, they cannot tell the strength of the magnetic field.

No lab time will be devoted to the use of reed switches because of their simplicity, but you should be aware of their common use as a cheap (~< $2) magnetic field sensor.

Hall effect sensors

The Hall effect, discovered in 1879 by Edwin Hall, is the production of a potential difference, the Hall voltage, across an electrical conductor in which electric current flows in the presence of a magnetic field. The force acting on the electrons, given by (1), causes them to drift toward one edge of the conductor, or Hall element, creating a potential difference across it, as illustrated in Figure 6. The direction of the potential difference is perpendicular to both the magnetic field and the current.

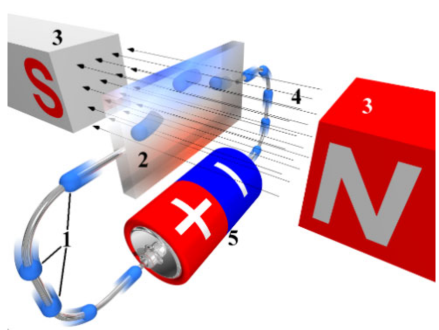


Figure 6. Hall effect diagram. Public domain, Hall_effect_A.png

The potential field vector, $\vec{E}$, (V/m) due to the Hall effect is given by the following equation where the current, $\vec{I}$, is typically held constant, $\vec{B}$ is the magnetic field vector, A is the cross-sectional area of the Hall element, and R_H is the Hall coefficient, whose value depends on properties of the Hall element and the charge carriers.

$$\vec{E} = R_H \frac{\vec{I} \times \vec{B}}{A} \tag{2}$$

This gives the potential that will develop and its direction (whether the electrons drift up, down, left, or right in the figure above). If we let θ be the angle between the current and the magnetic field, then the signed, scalar Hall voltage, V_H, can be obtained via the following equation in which d is the thickness of the Hall element measured perpendicular to $\vec{E}$. Most Hall effect sensors only have one pair of electrodes to detect voltage changes so the portion of V_H they detect is proportional to the component of $\vec{E}$ that points towards them.

$$V_H = \frac{R_H}{d}\left|\vec{I}\right|\left|\vec{B}\right|\sin\theta \tag{3}$$

Hall effect sensors are divided into two primary groups based on whether they produce an analog or digital output signal and are available in single- element and multi-element packages. Other options include: latching, continuous-time, bipolar, monopolar, ratiometric, linear, nonlinear, or temperature compensated, and many other functions specific for automotive applications.

The Allegro Hall Effect Sensor

For this lab, a continuous-time, ratiometric, linear Hall effect sensor will be used. Figure 7 below shows a functional block diagram of this sensor. It can operate using a supply voltage between 4.5 and 6 V, but it is designed for 5 V operation. This sensor has a quiescent output voltage that is 50% of the supply voltage, meaning that when no magnetic field is present and when supplied with 5 V, the sensor will return an output of 2.5 V. As the sensor is brought in range of a magnetic field, the output voltage will increase or decrease by 5.0 mV/G depending on the polarity of the field and the orientation of the sensor.

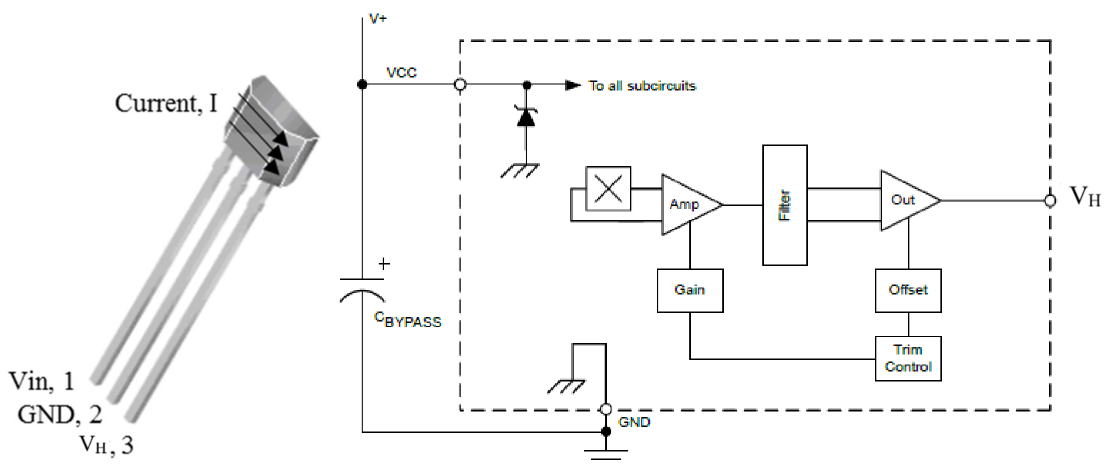


Figure 7. Allegro Hall Effect sensor diagram (left) and functional block diagram of the internal circuitry (right).

NOTE: The schematic includes a bypass capacitor labeled C_{BYPASS}. It is critical that this capacitor is in place when power is applied to the Hall effect sensor. Without this capacitor, the sensor will be damaged.

Practical sensor circuit

To use the Allegro Hall effect sensor a bypass capacitor (100nF) must be used to keep from damaging the sensor. Since the Hall Effect sensor has a small sensitivity, it is practical to amplify the signal. To keep the output in the range of 0-5V the reference of the amplifier has to be altered to output 2.5 V (quiescent voltage) when not in the presence of magnetic fields. When you amplify a signal, you will also amplify the noise. It may also be beneficial to filter the final output.

2.3 MCP 6004 Quad Op Amp

The MCP 6004 is a pin-for-pin match for the LM324 op-amp used in previous labs, but it is a single supply op-amp (meaning it only receives a positive supply voltage and ground on its power rails, and can only input/output positive voltage signals), and it has rail-to-rail design (meaning the range of its output voltage is exactly the same as the supply voltage, e.g. 0 to 5V). In contrast, the LM324 is a dual-supply op-amp (it can receive and output positive and negative voltages), but is not rail-to-rail (its output range is smaller than the supply range). While the LM324 amps are good for benchtop experiments with double-sided power supplies and Data Acquisition hardware, the MCP 6004 is a better match for use with Arduinos, which can only supply and receive 0 to 5V. *Be sure to apply power to the op-amp with the correct polarity or it will be damaged.* V_{SS}= GND and V_{DD}= +5V should be used for this lab.

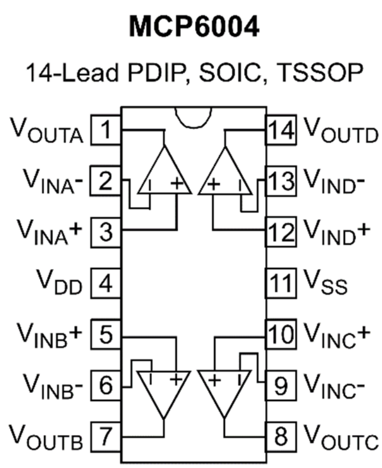
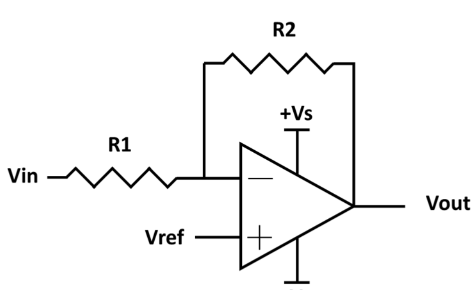


Figure 8. Pin out diagram of the MCP6004 op amp.

2.4 Referencing an Amplifier

Because the Hall effect sensor outputs 2.5V in the presence of no magnetic fields (we call this the quiescent voltage), and it is important to amplify the signal for practical use, it is necessary to amplify the signal with respect to 2.5V. To do this, we can use an inverting amplifier circuit with a non-zero reference voltage, as shown below.



$$i_2 = \frac{V_{out} - V_{ref}}{R_2}$$

$$i_1 = \frac{V_{ref} - V_{in}}{R_1}$$

$$\frac{V_{out} - V_{ref}}{R_2} = \frac{V_{ref} - V_{in}}{R_1}$$

$$V_{out} = \left(V_{ref} - V_{in}\right)\left(\frac{R_2}{R_1}\right) + V_{ref}$$

This version of an inverting amplifier will amplify the difference between the input voltage and reference voltage (V_{ref}), and then reapply an offset of V_{ref}. Therefore if we connect the output of the Hall effect sensor V_H to V_{in} of the amplifier circuit, and use V_{ref} = 2.5 V, the amplified output V_{out} will remain centered about 2.5 V, which will be convenient for reading with the Arduino.

2.5 Color Sensing

This lab also focuses on color detection using a RGB (Red-Green-Blue) LED with a phototransistor. This sensing technique basically illuminates an object using the RGB LED and then detects the light levels reflected by the object, Figure 9 (left). Typically, each color of the RGB LED is illuminated separately and the light reflected by the object for each color is sensed by the phototransistor. The detected RGB levels are then used to form a lookup table for a particular object. In lab, we will use a cube with each face of the cube covered in a different color tape. Since each sample color is different, each type of color reflects light uniquely and will have a unique signature. Once calibrated, this allows the sensor to detect each type of sample color.

Implementation of the sensor is also illustrated in Figure 9. As indicated, a light shield is placed around the RGB LED and photo transistor. It is important to guarantee that light from the LED only reaches the phototransistor if it bounces off an object. A slight lip, or elevated ridge, can also be provided to limit outside light from reaching the phototransistor. This would allow the sensor to be pressed against an object and nearly eliminate outside light from reaching the phototransistor. In this example, the phototransistor, RGB LED, and light shield are all mounted to a small segment of electronics protoboard. This allows reliable solder connections and mounting.

The circuit diagram indicating connection of the color sensor is also shown in Figure 9. The RGB LED in this example is a common anode (+) design. A 5V power source is connected to a single 330 Ω pull-up resistor, which then connects to the common anode (+) of the RGB LED. The resistor limits the current passing through the LED to prevent damage. The cathode wires of the LED then connect to the digital connections of the Arduino, labeled JP2. In this case, they are connected to digital I/O pins 5, 6, and 7, which are the 6th, 7th, and 8th pins on the JP2 header. You can connect them to any digital pin. When the pins are set to HIGH (i.e., 5 volts), no current flows through the LED. When a pin is set to LOW (i.e., 0 volts), current flows through the LED cathode connected to the pin and the LED illuminates.

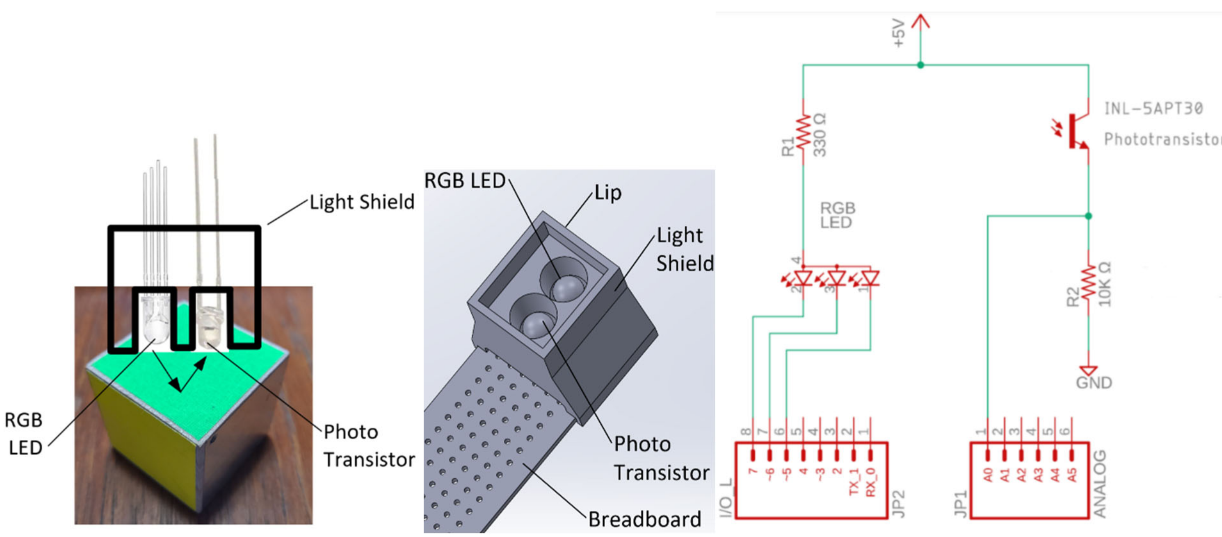


Figure 9. Illustration of color sensor (left), the color sensor light shield (middle), and the color sensor electrical connections to an Arduino (right).

The phototransistor is also shown in the circuit diagram. It uses a "pull-down" resistor configuration where the 5-volt supply is connected to the phototransistor, which is then connected to a $10\ k\Omega$ pull-down resistor. The phototransistor and resistor act like a voltage divider, where the voltage at their junction is connected to the A0 analog input of the Arduino. This is on the JP1 header as shown. When the phototransistor is not exposed to light (i.e., in darkness), the transistor does not allow current to pass and A0 measures ~0 volts. When exposed to light, however, the phototransistor allows current to flow, which raises the voltage measured at A0. The brighter the light, the higher the voltage measured at A0.

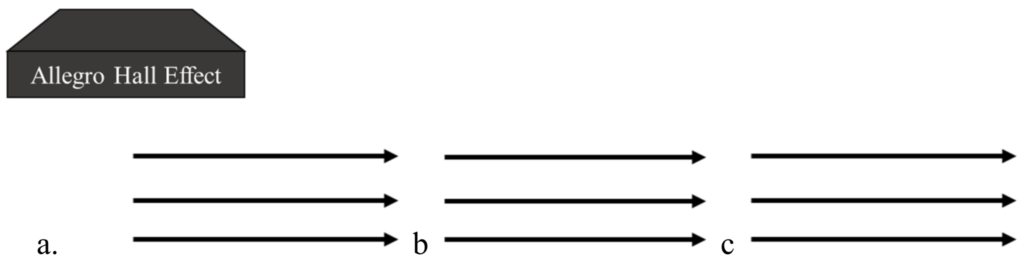
As a final note, the phototransistor itself does not distinguish color, only light intensity. Hence, the light shield and its lip are important for preventing outside light from contaminating its measurements.

3. Pre-Lab Exercises

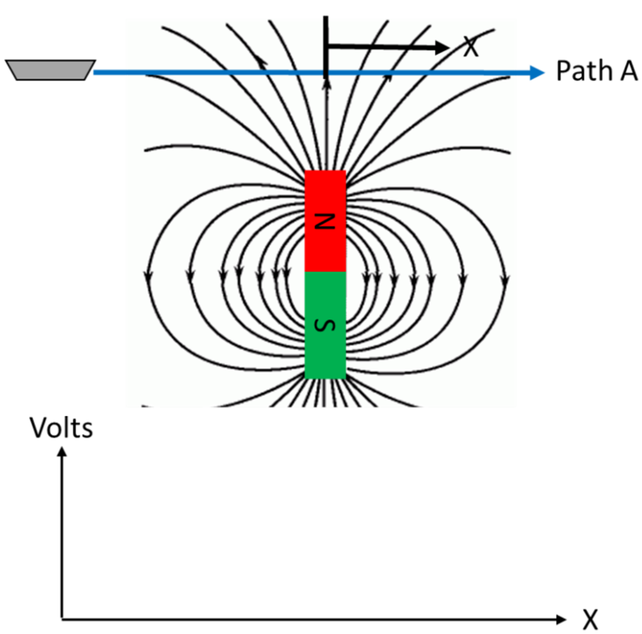
1. What is the intended supply voltage for the Allegro Hall effect sensor?

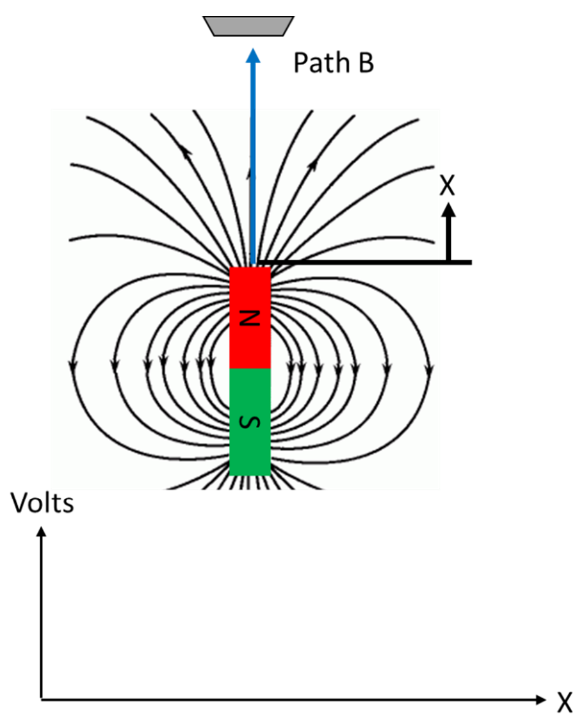
2. What is the sensitivity of the Allegro Hall effect sensor in mV/G?

3. For the following magnetic fields, draw the Allegro Hall effect sensor in the orientation that results in: (a) the maximum (b) the minimum (c) a 35% change in voltage (from quiescent) output. Label necessary orientation angles.



4. In the following figures a Hall effect sensor passes along the path through a magnetic field. Sketch the sensor response assuming 2.5V is at maximum output and 0V at no output. Do not worry about positive or negative voltage. Label the max and min voltage as well as the 0 position in x.





5. The table below shows some readings of the raw/unfiltered output of a Hall effect sensor vs. distance from a magnet. Recall that in the presence of no magnetic field, the sensor would output 2.5 V. As shown in the table, the voltage from the sensor increases from 2.5 V to 5.0 V as the magnet is brought closer. You can assume that if the polarity of the magnet were reversed, the readings would decrease from 2.5 to 0.0 volts as the magnet is brought closer to the sensor. Your goal in this problem is to design a first-order active low-pass filter to amplify and filter the Hall effect sensor output, such that the output of the amp/filter is still 2.5 V when no magnetic field is present, but saturates (V_{out} = 0 or 5 V) when the magnet is 3 cm away, and noise above 100 Hz is attenuated.

Distance (cm)	V_H
0	5.00
1	5.00
2	3.35
3	2.78
4	2.62
5	2.58
6	2.54

a. Start with the reference amplifier circuit in Section 2.4, and think about how you can turn it into a low-pass filter (Hint: Recall how we made active low-pass filters in Lab 6). Also think about how to provide the proper reference voltage, V_{ref} = 2.5 Volts, using the 5 V power supply from the Arduino. Draw the intended circuit diagram. Properly label each component name, supply voltage value, and input/output voltage labels.

b. Perform the calculations for determining component values.

4. Laboratory Exercises

4.1 Check the Hall effect circuit

4.1.1 Build the hall effect amplifier-filter circuit based on the diagram provided by the TA. (Hint: It will be similar to the circuit that you designed in the prelab, so we do not want to say too much about its specifics in the handout.)

- Insert the hall effect sensor in the 3-pin extension provided. Note that the bypass capacitor indicated in Figure 7 is connected to the sensor as closely as possible to limit current inrush and electrical noise from damaging the sensor. They are very sensitive.
- Make sure the connections to the hall effect sensor are correct. If the power is connected incorrectly the sensor could be damaged.
- **DO NOT use ±12V**
- **DO NOT turn power on until TA checks your circuit**

4.1.2 Open your Lab3_GUI. Configure it to use 1000 samples at 1000 Hz sampling rate.

- Connect ACH0 to the output of the Hall effect sensor (pin 3)
- Connect ACH1 to the output of the Amplifier/Filter circuit

4.1.3 Look at the voltage measured when the magnet is present and not present. Remove the magnet from the sensor and record the quiescent voltage (e.g., the voltage when the magnet is removed) from ACH0 in Section 4.5 Student Work and Tables.

4.1.4 Adjust the potentiometer in the circuit until ACH1 matches the quiescent voltage.

Have a TA check your progress.

4.2 Output vs Distance

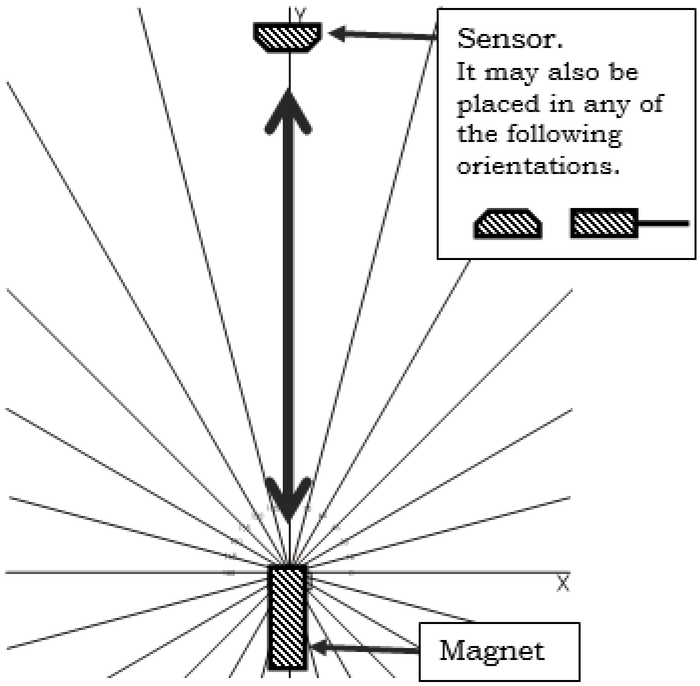


Figure 10. Diagram illustrating the magnet positioned at different distances from the sensor.

Record data in Section 4.5 Student Work and Tables (or Excel or MATLAB)

4.2.1 Place the angular grid provided on the bench top and place the magnet on it in the orientation shown above.

4.2.2 Move the sensor along the Y-axis until you reach the saturation voltage at ACH1. Record the voltage and the distance (cm) from the magnet face in the table in Section 4.5 Student Work and Tables (Hint: using MATLAB or Excel may be useful for later reference).

4.2.3 Move the sensor back in 1 cm increments and record the voltage and distance from the magnet. Keep the sensor at the same height from the benchtop while doing so. Repeat until the change in voltage becomes negligible.

4.2.4 Be sure to save the data (e.g. USB drive or cloud storage) for the post-lab.

Have a TA check your progress.

4.3 Output vs orientation

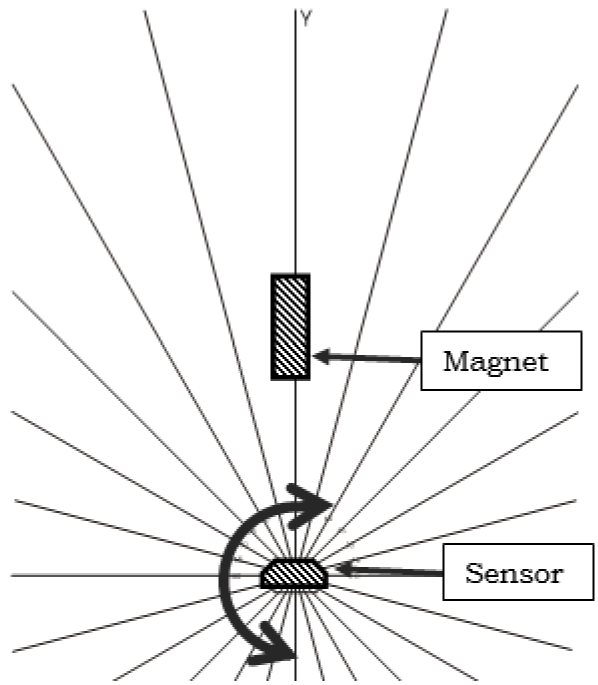


Figure 11. Diagram indicating the magnet placed at different orientations to the sensor. Note that the magnet is placed at 90° relative to the sensor (e.g. the horizontal line to the right of the sensor is 0° and the horizontal line to the left of the sensor is 180°).

Record data in Section 4.5 Student Work and Tables (or Excel or MATLAB)

4.3.1 Place your magnet at an appropriate distance was from the sensor so that the circuit saturates at the orientation shown above. It should be on the Y axis with the body of the magnet pointing toward the focal point along the Y axis. Note the distance between the magnet and the center of the sensor.

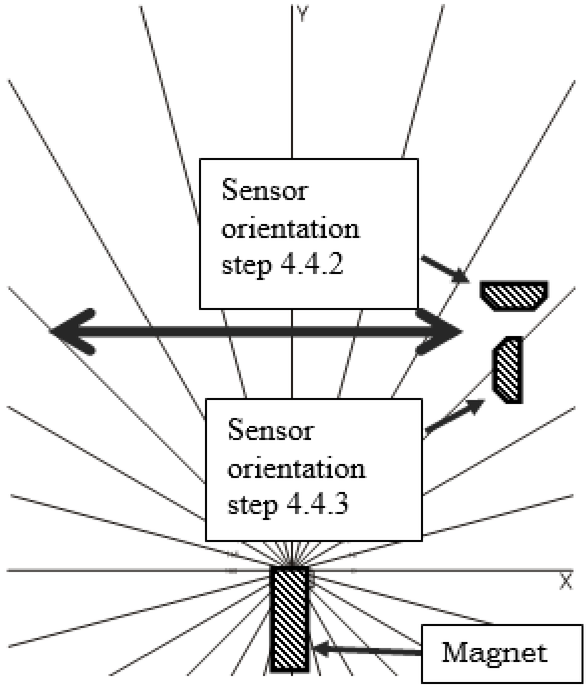
4.3.2 The orientation in the above step is actually the 90° position of the magnet with respect to the sensor. The zero-degree position is the horizontal line to the right of the sensor.

4.3.3 Using the ray pattern as a guide, rotate the magnet around the sensor vertical from 90° all the way around in 30° increments. Be sure to maintain the same distance between the sensor and magnet as noted in step 4.3.1. The magnet should always be parallel to the line and pointed toward the sensor. Record each orientation and the corresponding amplifier output voltage in Section 4.5.

4.3.4 Be sure to save the data (e.g. USB drive or cloud storage) for the post-lab.

Have a TA check your progress.

4.4 During "Drive By"



4.4.1 Place the magnet back at the origin as before and draw a line parallel to the X-axis on the sheet at a distance where the reading is just below full strength when at midline

4.4.2 Orient the hall effect as shown in the figure above. Move it along the line you drew, recording voltage and position measurements (1 cm increments) relative to the magnet (0 cm at midline) in section 4.5.

4.4.3 Repeat the above step at the orientation shown in the figure above for this step.

4.4.4 Plot the data from the two orientations and show them to your TA.

Have a TA check your progress

4.5 Phototransistor Color Sensor Output

In this step you will collect data using colored blocks and the color sensor. This data will be used to calibrate the sensor to the different colors that you expect to see in the competition. The post lab exercise will guide you through creating a lookup table for sensor values corresponding to each color on the block. You will then use that lookup table in PM8 for detecting the different colors using the color sensor.

4.5.1 Download and open the Active_Color_Sensor.ino file.

4.5.2 The phototransistor and color RBG LED are assembled on a breadboard. Verify that the breadboard is connected to the correct Arduino pins, similar to what is shown in Figure 9, but the digital pins used should be 22, 24, and 26. It may be valuable to take a picture of the circuit and system for your reference since you will need to recreate this in your project.

4.5.3 Open the serial monitor. For each block color **(blue, red, yellow)** do the following:

- Position the color LED and phototransistor assembly just above the sample block
- Type “g” into the serial monitor and press enter. The Arduino program will change LED colors (i.e., , blue, red, and green) and obtain phototransistor data points for each LED color. The sampled data will be returned on the serial monitor. There should be 30 data points reported for each color, reported as 30 rows of data with 3 columns of comma delimited data corresponding to when the red, green, and blue LEDs were illuminated.
- Be sure to *save the data* by copying the serial monitor, pasting to the “Notepad”, then saving the file as a “.csv”. This way the file will already be comma separated instead of pasted into excel all in a single column.

Have a TA check your progress.

4.6 Student Work and Tables

Work for section 4.1

Quiescent voltage = _________________V

Table for Section 4.2

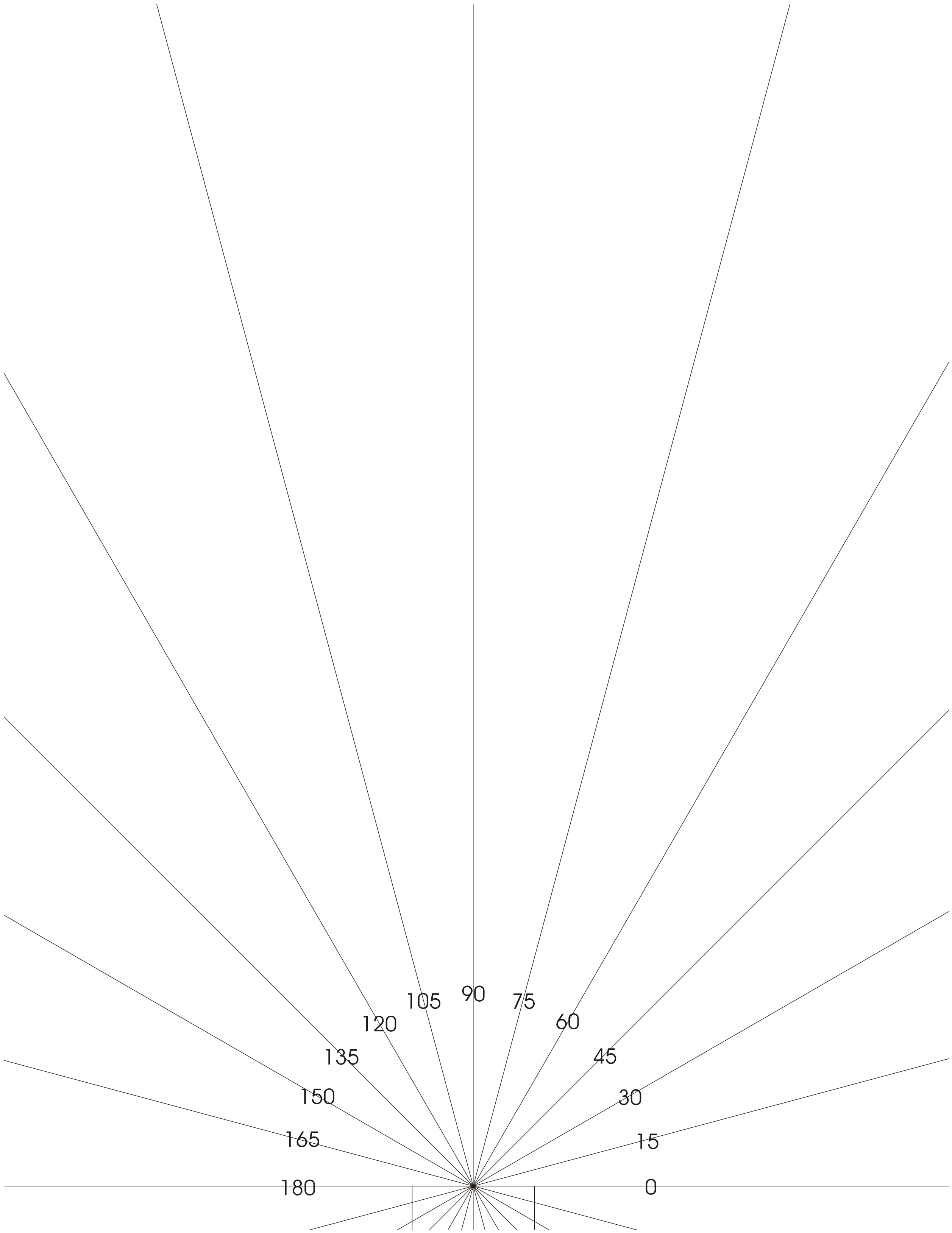
Distance (cm)	Voltage (V)

Table for Section 4.3

Angle (deg)	Voltage (V)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	
330	
360	

Table for Section 4.4

X (cm)	Voltage 4.4.2 (V)	Voltage 4.4.3 (V)


105
90
75
120
60
135
45
150
30
165
15
180
0

5. Post-Lab Exercises

1. For this problem refer to your data obtained in section 4.2 and answer the following questions:
   a. Plot the data from Table 4.2 (Voltage on the y-axis vs Distance on the x-axis) in MATLAB.
   b. What is the *effective* distance range {min, max} of the Hall effect output (either North or South orientation of the magnet).
   c. Is the Hall effect sensor voltage linear with respect to distance (distance between magnet and sensor)? How does the Hall effect sensitivity to distance (V/mm) change as the distance between magnet and sensor changes?
   d. How does changing the gain of your filter affect the sensitivity and range of distance you can measure with your Hall Effect sensor?

2. Using MATLAB plot and make a fit line of your data from 4.3. For the fit line, you should have an equation that has the following form: V = f(θ). Consider the mathematic relationship for voltage and orientation discussed in the lab documentation. (Hint: To fit a cosine/sine function you must fit a line to experimental data Voltage vs cos(θ)/sin(θ)). Plot your experimental data and your fit equation on the same plot (Voltage on y-axis and degrees on x-axis). Display the fit equation on your graph. Attach your plot to the post lab.

3. Color Sensing Characteristics: Analyze the data from section 4.5 to find the mean and standard deviation for each combination of block color and LED color. With this data, complete the table below showing the mean sensor reading, $\bar{x}$, and standard deviation, σ, corresponding to each block color / LED combo.

	Sensor Reading w/blue LED		**Sensor Reading w/red LED**		**Sensor Reading w/green LED**	
	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Blue Block						
Red Block						
Yellow Block						

4. Based on your Table in problem 3, you will now define a range of sensor values for each color of block that will allow you to uniquely identify the color of the block based on the sensor readings. For example, for a block to be classified as "blue", the sensor readings with the blue, red, and green LEDs would all have to fall within their respective ranges defined for that block.
In each case, the range should be based upon the mean value and standard deviation, while also considering the range of the Arduino (i.e., it uses a 10-bit A/D, so reported values will range from 0 to 1023.) Assuming your data has a normal (Gaussian) distribution, there should be a 99.7% probability that any data point lies within 3 standard deviations of the mean. Therefore, you should set each range to span at least 3 standard deviations above and below the mean, but not exceeding the range of the Arduino, and small enough that the color of the block can be uniquely identified (i.e. at least one of the 3 sensor ranges for the blue block must not overlap with the corresponding range for the green block, etc).

For PM8, you will use this table to create an algorithm to identify the color of a sensed block.

	Sensor Range w/blue LED		**Sensor Range w/ red LED**		**Sensor Range w/ green LED**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Blue Block						
Red Block						
Yellow Block						

6. Project Milestone

The purpose of PM 8 is to implement color sensing and magnetic sensing on your robot. For the competition, it will be advantageous to sense the color of each block, and to use magnetic sensing to determine whether the block dispenser is ready to be activated. Towards this goal, each team should implement a Hall Effect sensor and a color sensor and position them in the appropriate spots on their robot. During Lab 9, your team will present the following in a 5-10-minute presentation. Upload a copy of your presentation on canvas before Lab 9 begins. Your presentation should include the following.

Presentation (25 points)

- Discuss each team member contributions for this week.

Hall Effect sensors

- Discuss how you will use Hall Effect sensor(s) to accomplish tasks in the project.
  - How many will you use?
  - Discuss your magnet sensing method.
- Implement the Hall effect sensors
  - Provide a photo of the sensor(s) installed on the robot
  - Discuss circuitry, post-processing, and positioning of the sensor.

Color sensors

- Discuss how you will use Color sensor(s) to accomplish tasks in the project.
  - How many will you use?
  - Discuss your color sensing method.
- Implement the Color sensors
  - Provide a photo of the sensor(s) installed on the robot
  - Discuss circuitry, post-processing, and positioning of the sensor.

Update state transition diagram

- Now that you have implemented your color and magnetic sensors, update your state transition diagram to incorporate any changes. Be sure to incorporate feedback from previous milestones.

Demonstration (50 Points)

In lab, you will place your robot by the block dispenser on the competition field in the position/configuration you plan for it to be in when obtaining a block. When your Hall-Effect sensor detects the dispenser is level, your robot should push the button to activate the dispenser and receive a block. When your robot receives a block, it should then detect the color (Red, Blue, Yellow), and display the identity of the block on the serial monitor. You may operate your robot with your PC tethered to your Arduino Mega or Uno (i.e. wireless communication is not required for this demo). Note that the primary purpose of this demo is to demonstrate your sensing. Even if your block receiving functionality is not working reliably, you can still earn full credit as long as you successfully demonstrate the functionality of your magnetic and color sensing.