Question 1: Sensing: Circuit to Sense Rigid Side Walls

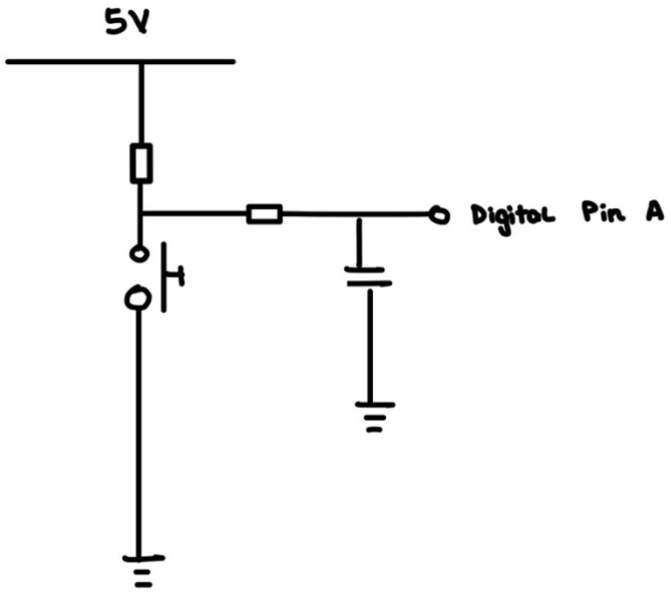

Figure 1: NO pushbutton circuit

The diagram is shown in Figure 1 above. The components we have selected are resistors, a capacitor, and the NO push button. A NO pushbutton is a push button that, in its default state, makes no electrical contact with the circuit. Only when the button is pressed down does it make electrical contact with the circuit. On the left side of the diagram, we added a pull-up resistor to keep the pin from hanging, that prevents pins for an uncertain voltage. The right side of the diagram shows a RC Low-pass filter that passes signals with a frequency lower than a selected cut-off frequency and attenuates signals with frequencies higher than the cut-off frequency. We added an RC filter to prevent bouncing. bouncing occurs when a switch is first pressed down, it will switch between on and off continuously for a short time before having a good connection with the circuit, while leads to multiple transitions from a single input. The capacitor in the RC filter helps with debouncing as it limits how quickly the voltage changes over time. When we press down the button, the internal electrical is connected to the circuit and leads to the external through the pin after passing through the resistor and the low-pass filter. The left resistor in the circuit can take a value of around 1 kΩ.

Question 2- Sensing: Circuit to Sense Front Unstable Walls

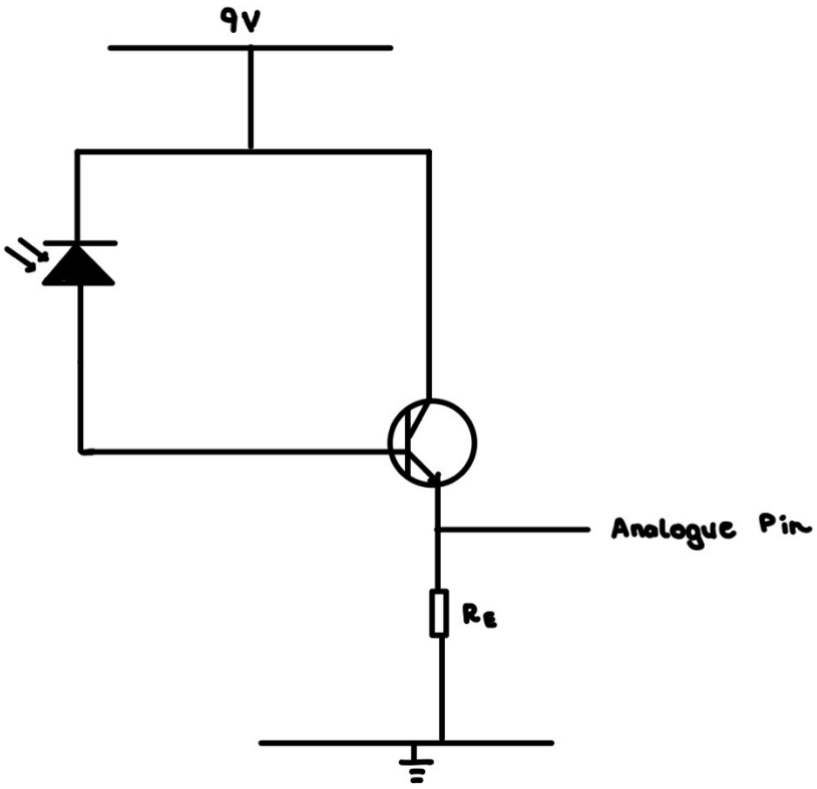

Figure 2: Photodiode Circuit

The circuit in Figure 2 shows a circuit for reverse biasing a photodiode with a constant voltage while producing a voltage that is linearly related to the photocurrent. The constant voltage is provided by the 9V battery, which is directly connected to the collector terminal of the n-type BJT and the photodiode. The photodiode is in reverse bias and connected to the n-type BJT base. When the photodiode is in reverse bias, current will only flow through when light is incident on it, generating a photocurrent. Since the photocurrent is connected to the base of the n-type BJT, the photocurrent acts as the base current. The collector current and the base current have a linear relationship shown in the below equation, where β is the transistor current gain.

$$I_C = \beta I_B$$

The emitter current is the sum of the base and the collector current shown below.

$$I_E = I_C + I_B$$

Since β is a large value (around 50-200), this causes the photocurrent to be negligible compared to the collector current, therefore we can approximate that the collector current is equal to the emitter current.

The circuit is arranged in an emitter follower configuration as the output is taken from the emitter, therefore the emitter voltage is also the output voltage. The output voltage is determined by the equation below.

$$V_o = I_E * R_E$$

Since the emitter current is approximately the collector current and the collector current is proportional to the photocurrent, the output voltage can be rewritten as:

$$V_o = \beta I_{photo} * R_E$$

From this equation, we can see that the photocurrent and the voltage produced has a linear relationship while the photodiode is in reverse bias.

The output of the circuit is connected to one of the analogue pins of the Arduino. This is so we can see the change in voltage can be observed in the serial monitor of the Arduino application.

If DC voltage is in series with a resistor and the photodiode, the reverse bias voltage would decrease as the photocurrent increase. An n-type BJT in the emitter follower configuration is the method we chose to combat this.

Question 3: Actuation: Motor Driver Circuits (Forward)

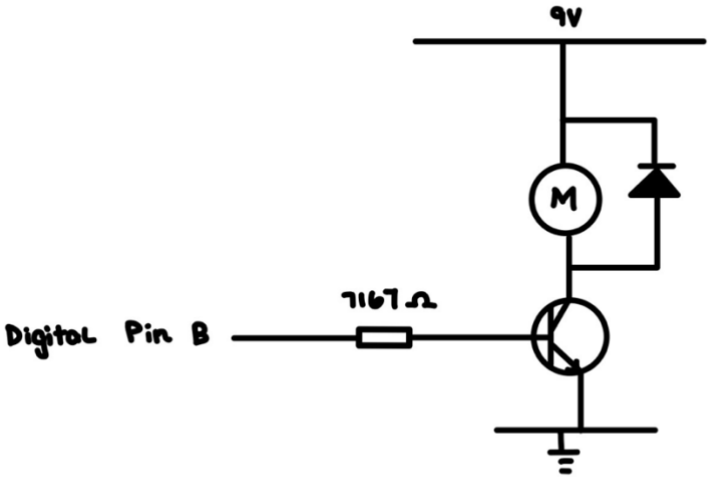

Figure 3: Motor Circuit (Forward)

The motor circuit that drives the robot forward is shown in Figure 3 above. There is a constant voltage source with 9V in series with a Motor and a NPN diode, and the diode connected in parallel to the motor. There is a 7167 Ω resistor connected to the base of n-type BJT which is connected to the one of the digital pins of the Arduino. There are two motors that drives the robot forwards; therefore, we will need two of the circuits shown in Figure 3, connected to the same digital pin.

The aim of using diode is to prevent the sudden change in current, because motor have inductance and it cannot bear the sudden change in current. When BJT is cut-off, the motor will lead to a significant increase in voltage at the collector of BJT and might breakdown the transistor.

To obtain the value of the resistor, there are parts of the circuit that need to be considered. The motor requires 0.12 A to turn on. The current flowing through the motor is also the collector current, therefore, the base current can be found using the equation below.

$$I_B = \frac{I_C}{\beta}$$

The current flowing through the resistor is also the base current and since we know the base-emitter voltage is around 0.7 V, the resistor can be calculated using the equation below.

$$R = \frac{5 - 0.7}{I_B}$$

The value we obtained is 7167 Ω.

Question 4: Actuation: Motor Driver Circuits (Left and Right)

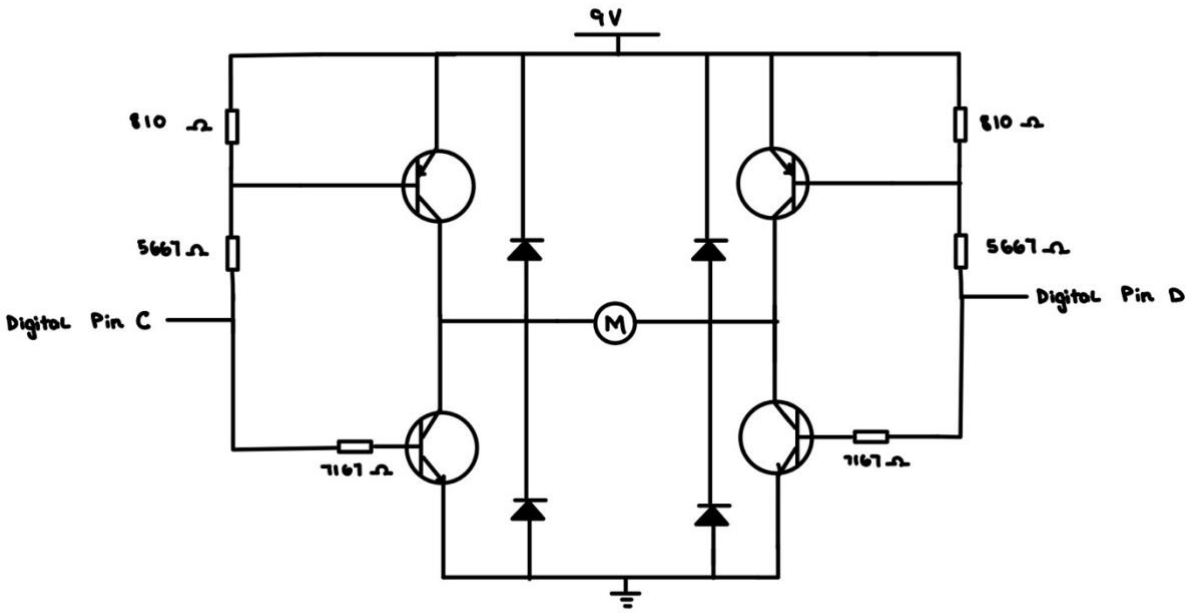

Figure 4: Motor Circuit (Left and Right)

Because the current that the Arduino can drive is only 0.04A, it means that the Arduino cannot drive the motors 3, 4. So you need to use BJTs and a 9V battery. At the same time, to allow the motor to rotate both ways, it is necessary to use two NPN and two PNP BJTs to build an H bridge. The p-type BJTs are connected to the potential divider, while the n-type BJTs are connected to a single resistor. One pair of n-type and one p-type BJT are connected to a single digital pin while the other pair is connected to another digital pin. The BJTs acts as switches in the H-bridge circuit. The two types of BJT perform differently. At LOW voltage, the n-type resistor will turn off, while the p-type resistor will turn on while at HIGH voltage, the n-type resistor will turn on while the p-type resistor will turn off. The two pins will need to be different for current to flow through the motor and to ground.

At the same time, four flyback diodes should be added in the H bridge as shown in the figure. Because the motor has inductance, when the BJT is cut off suddenly, the motor will generate a large reverse emf to break down the BJT, allowing the current to continue to conduct. This would be extremely damaging to the BJT. Adding 4 flyback diodes can make the current flow through two of the diodes when the BJT is off, thus protecting the BJT.

The current of the motor needs to be maintained at 0.12A. Since the value of β is large, the base current is negligible compared to the emitter current, so for an active BJT:

$$I_C = I_E = 0.12\ A$$

For the two NPN BJTs:

$$R = \frac{V_{CC} - V_{BE}}{I_B} = \frac{V_{CC} - V_{BE}}{I_C/\beta} = \frac{5 - 0.7}{0.12/200} = 7167\ \Omega$$

For two PNP BJTs,

Because when VBE<0.5V, BJT is off, and the output of Arduino is 5V during this time.

$$9 - (5 + (9 - 5))\frac{R_2}{R_1 + R_2} \leq 0.5$$

$$\frac{R_2}{R_1 + R_2} \geq \frac{7}{8}$$

When the Arduino outputs 0V, the BJT is turned on, and VBE=0.7. During this time:

$$I_{R2} = I_{R1} + I_B$$

$$\frac{8.3}{R_2} = \frac{9 - 8.3}{R_1} + \frac{0.12}{200}$$

When $R_2 = 7R_1$

R1=809.5Ω

R2=5667Ω

Question 5 – Planning: Pseudocode

Initializing motion direction (to the left)

Declaring an array for storing photodiode readings

//record the readings over a certain period of time

Main loop: run forever

Record the current sensor reading into the array

//overwriting the values if the array length is exceeded

Traverse the array to find the maximum value

If it is greater than the global maximum

Record the maximum value

Traverse the array to find the minimum value

If it is smaller than the global minimum

Record the minimum value

Calculate the median (average of the global maximum and global minimum)

Calculate the average value of the array

If the average value of the array is smaller than the calculated median

//It means there is a big gap in front of the robot

Turn off motors 3 and 4

Loop until the sensor reading is less or equal to the global minimum

Read the sensor reading (do not record it in the array)

Turn on motors 1 and 2

Turn off motors 1 and 2

Continue to the next iteration of the main loop

If the left button or right button is **HIGH**

//it means the robot hit the wall on the left

Switch Digital Inputs of both pins of H-bridge

//to change directions

Loop until the left button or right button is released

Drive motors 3 and 4 according to the current direction

Continue to the next iteration of the main loop

Drive motors 3 and 4 according to the current direction

Question 6: Inclusivity and Diversity

In this part, we chose Datong Coal Mine from China as our ideal mine.

The Datong Coal Mine, located in China, is owned by the Datong Coal Mining Group, and has played a significant role in the country's economic growth and energy production. In this research, we will go into the history of the mine, explore its current state, analyze the revenue it generates, and examine the ways in which it benefits the local society and contributes to global energy demands.

1.History of the mine: (Jiahua Lv)

The Datong Coal Mine has a rich history that dates back several centuries. It was first established during the Ming Dynasty (1368-1644) and has since been a crucial source of coal for China's energy needs. The mine has witnessed extensive development and modernization over the years, adapting to changing technologies and remains a vital asset to China.

2.Current State: (Anthony Peng)

From the latest information available, the Datong Coal Mine continues to play a major role in China's coal industry. It covers a vast area and employs a significant number of workers, making it one of the largest coal mines in the country. Advanced mining techniques and technologies are employed to maximize efficiency, productivity, and safety. The mine's infrastructure includes tunnels and conveyor belts to extract and transport coal effectively.

Due to the environmental impacts, some of the mines in Datong are not active anymore, however Datong Coal mine is still active.

3.Revenue Generation: (Dingli Zhang)

The Datong Coal Mine generates substantial revenue for the operators and the local government. The mine produces millions of coals annually, supplying energy to power plants and industrial facilities across China. The revenue generated from coal sales contributes significantly to the national economy, supporting infrastructure development, job creation, and social welfare programs.

During the year 2003-2012, the coal prices were at an all-time high. There were many employees at the Datong Coal Mine Group and the profit on coal was high. However, during 2013, the price of coal started to drop, therefore decreasing the revenue of Datong Coal Mine.

4.Benefits to the Local Society: (Haoyu Gu)

The presence of the Datong Coal Mine has brought numerous benefits to the local society. Firstly, it provides stable employment opportunities for thousands of workers, directly supporting livelihoods and reducing unemployment rates in the region. Additionally, the mine's operations spur economic growth in surrounding communities by creating demand for goods and services, such as housing and food.

Furthermore, the mine invests in social development projects, including education, healthcare, and infrastructure improvements, improving the overall quality of life for the local population. By supporting community development, the Datong Coal Mine plays a vital role in uplifting the social and economic conditions of the area.

5.Global Impact: (Nathan Yuen)

China is the world's largest consumer of coal, and the mine's production plays a big role in meeting domestic energy demands. Coal from the Datong Mine contributes to the generation of electricity to homes and power industries throughout the country.

However, coal mining, especially at the Datong Mine, raises environmental concerns due to its carbon emissions which contribution to air pollution. This could affect the quality of life of the locals negatively and could lead to other hazards as well.

At around 2015, the city of Datong has been moving away from coal as their one and only source of power under the slogan “Datong Blue” because of air pollution. Although it is harder for them to earn revenue from coal mining, the city has used other methods to boost their economic growth, such as tourism. Because of this rapid transition of coal to renewable energy, it caused disparities in the city, however, the city of Datong became cleaner and ranked for first in air quality out of the eleven cities in Shang Xi.

References:

1. https://dcmgcl.en.china.cn/about.html#:~:text=The%20strategically%20goal%20of%20Datong%20Coal%20Mine%20Group,aluminum%20oxide%2C%20and%20600%2C000%20metric%20tons%20of%20methanol.
2. http://www.chinasdcoal.org.cn/XHDT/01211372.html
3. http://www.leadingir.com/trend/view/6111.html
4. https://en.wikipedia.org/wiki/Datong_Coal_Mining_Group
5. https://madeinchinajournal.com/2020/04/28/the-coal-transition-in-datong-an-ethnographic-perspective/