

# Maze Runner Robot

## SLG46537

This application shows how to interpret data from different sensors and how to design a robot to autonomously solve a maze with a GreenPAK™ IC.

This application note comes complete with design files which can be found in the References section.

## Contents

|                                                                     |    |
|---------------------------------------------------------------------|----|
| 1. Terms and Definitions .....                                      | 3  |
| 2. References .....                                                 | 3  |
| 3. Introduction .....                                               | 4  |
| 4. Hardware.....                                                    | 4  |
| 5. Algorithm Description .....                                      | 7  |
| 6. Design .....                                                     | 9  |
| 6.1 Interpretation / Processing of Data from Distance Sensors ..... | 9  |
| 6.2 ASM States and motor outputs.....                               | 10 |
| 7. Conclusion .....                                                 | 13 |
| 8. Revision History .....                                           | 14 |

## Figures

|                                                           |    |
|-----------------------------------------------------------|----|
| Figure 1. Distance-Voltage Graph .....                    | 5  |
| Figure 2. Tracker Sensor .....                            | 5  |
| Figure 3. Pololu Wheel Encoder, Motor and Wheel .....     | 6  |
| Figure 4. Encoder Outputs.....                            | 6  |
| Figure 5. Motor Driver Circuit Board.....                 | 6  |
| Figure 6. Inputs and Outputs of GreenPAK Chip .....       | 7  |
| Figure 7. Simplified Algorithm.....                       | 7  |
| Figure 8. Turn Right Sequence.....                        | 8  |
| Figure 9. Collision Avoidance Algorithm.....              | 8  |
| Figure 10. Final Algorithm GreenPAK .....                 | 8  |
| Figure 11. ACMP's Settings.....                           | 9  |
| Figure 12. Wall Detection Circuit .....                   | 10 |
| Figure 13. Wall Collision Circuit.....                    | 10 |
| Figure 14. Connection Matrix Output RAM.....              | 11 |
| Figure 15. Move Forward Delay Settings and Circuits ..... | 12 |
| Figure 16. ASM Inputs and Outputs .....                   | 12 |
| Figure 17. Motor Outputs.....                             | 13 |

## Tables

|                                                   |    |
|---------------------------------------------------|----|
| Table 1. Motor Movement According to Inputs.....  | 10 |
| Table 2. PWM Table .....                          | 11 |
| Table 3. Robot Movement According to Inputs ..... | 11 |
| Table 4. Robot Movement with PWM .....            | 11 |

## 1. Terms and Definitions

|      |                                                   |
|------|---------------------------------------------------|
| ASM  | Asynchronous State Machine                        |
| IC   | Integrated circuit                                |
| IEEE | Institute of electrical and electronics engineers |
| IR   | Infrared                                          |

## 2. References

For related documents and software, please visit:

[GreenPAK Programmable Mixed-Signal Products | Renesas](#)

Download our free Go Configure Software Hub [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Renesas IC.

[1] [Go Configure Software Hub](#), Software Download and User Guide, Renesas Electronics

[2] [AN-CM-215 Maze Runner Robot.gp](#), GreenPAK Design File, Renesas Electronics

[3] [GreenPAK Development Tools](#), GreenPAK Development Tools Webpage, Renesas Electronics

[4] [Application Notes](#), GreenPAK Application Notes Webpage, Renesas Electronics

[5] [SLG46537 Datasheet](#), Renesas Electronics

### 3. Introduction

Maze-solving robots originate from the 1970s. Since then, the IEEE has been holding maze solving competitions called the Micro Mouse Contest. The aim of the contest is to design a robot that finds the midpoint of a maze as quickly as possible. The algorithms used to quickly solve the maze typically fall into three categories; random search, maze mapping, and right or left wall following methods.

The most functional of these methods is the wall following method. In this method, the robot follows the right or left side wall in the maze. If the exit point is connected to the outer walls of the maze, the robot will find the exit. This app note uses the right wall following method.

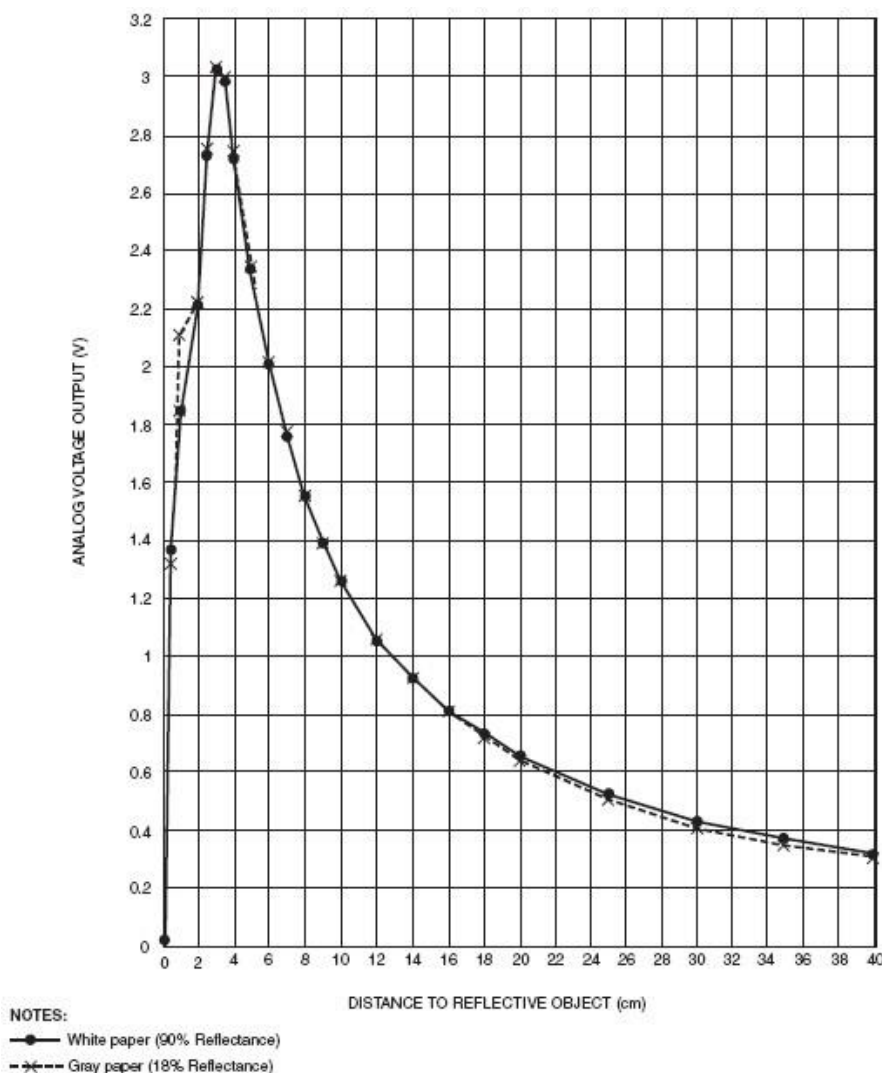
### 4. Hardware

This application uses:

- 2 Sharp analog distance sensors
- Tracker sensor
- Encoder
- Motors and motor driver
- GreenPAK™ SLG46537V
- Voltage regulator, robot chassis etc.

We will use the analog distance sensor to determine the distances to the right and front walls. The Sharp distance sensors are a popular choice for many projects that require accurate distance measurements. This IR sensor is more economical than sonar rangefinders, yet it provides much better performance than other IR alternatives.

There is a nonlinear, inverse relationship between the output voltage of the sensor and the measured distance. The plot showing the relationship between the sensor output and the measured distance is shown in [Figure 1](#).



**Figure 1. Distance-Voltage Graph**

A white line against a black color ground is set as the target. We will use the tracker sensor to detect the white line. The tracker sensor has five analog outputs, and the outputted data is influenced by the distance and the color of the detected object. The detected points with higher infrared reflectance (white) will cause a higher output value, and the lower infrared reflectance (black) will cause a lower output value.



**Figure 2. Tracker Sensor**

We will use the pololu wheel encoder to calculate the distance the robot travels. This quadrature encoder board is designed to work with pololu micro metal gearmotors. It functions by holding two infrared reflectance sensors inside the hub of a Pololu 42 mm × 19 mm wheel and measuring the movement of the twelve teeth along the wheel's rim.



Figure 3. Pololu Wheel Encoder, Motor and Wheel



Figure 4. Encoder Outputs

A motor driver circuit board (L298N) is used to control the motors. The INx pins are used to direct the motors, and the ENx pins are used to set the speed of the motors.

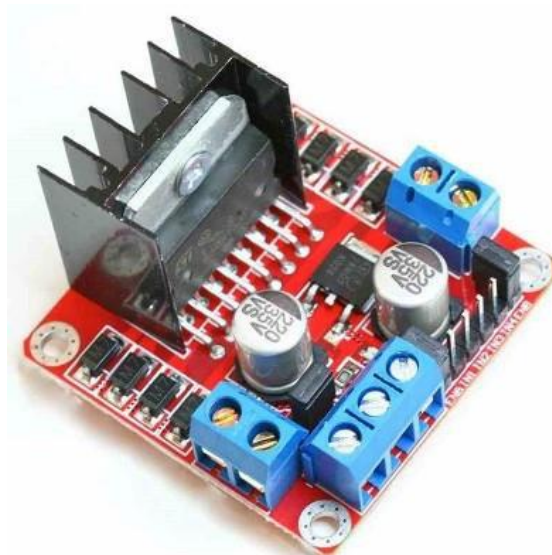


Figure 5. Motor Driver Circuit Board

Also, a voltage regulator is used to reduce the voltage from the battery down to 5 V.

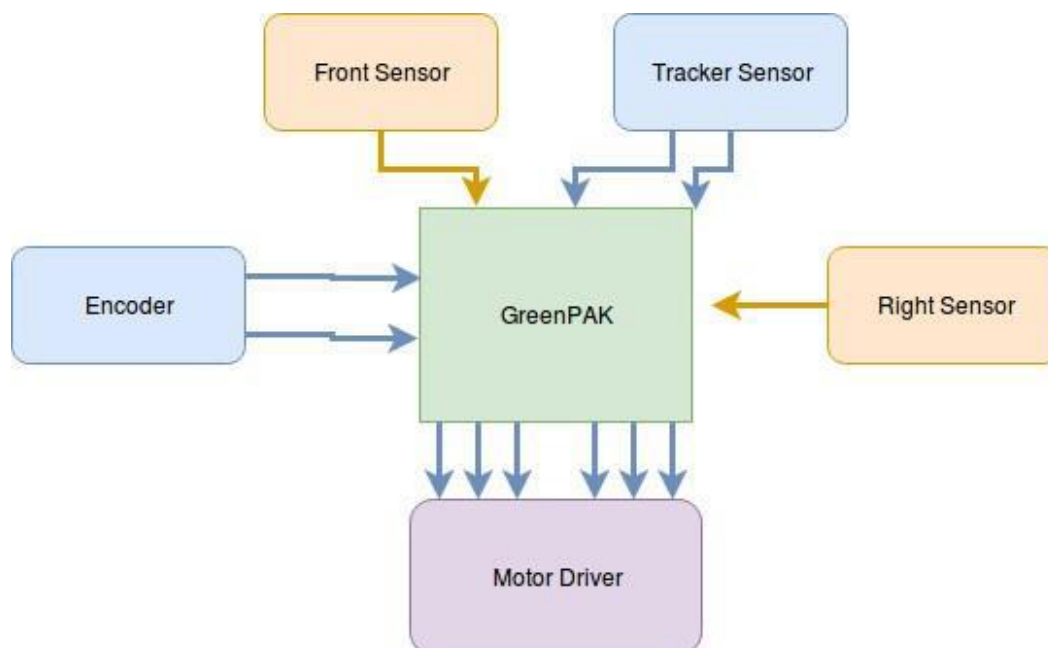


Figure 6. Inputs and Outputs of GreenPAK Chip

## 5. Algorithm Description

This app note incorporates the right wall following method. This is based upon organizing direction priority by preferring the rightmost possible direction. If the robot cannot detect the wall on the right, it turns to the right. If the robot detects the right wall and there is no wall in front, it goes forward. If there is a wall to the right of the robot and the front, it turns to the left.

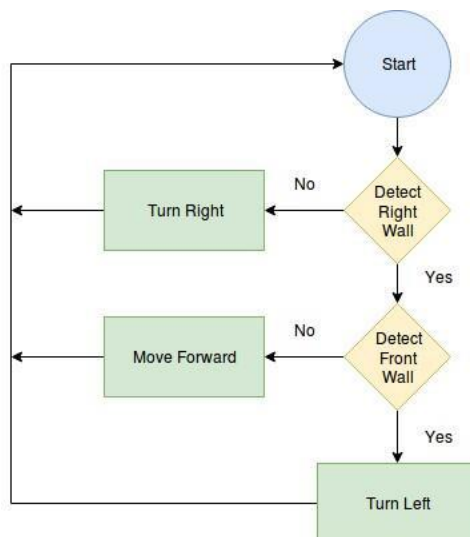
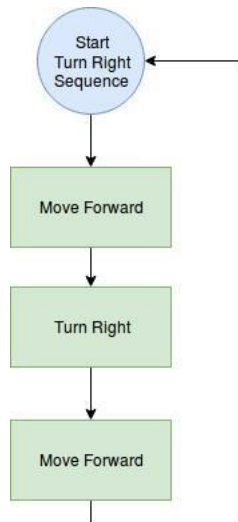


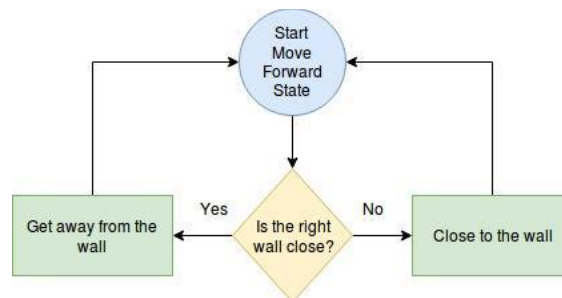
Figure 7. Simplified Algorithm

An important note is that there is no wall for reference after the robot has just turned to the right. Therefore “turning right” is accomplished in three steps. Move forward, turn right, move forward.



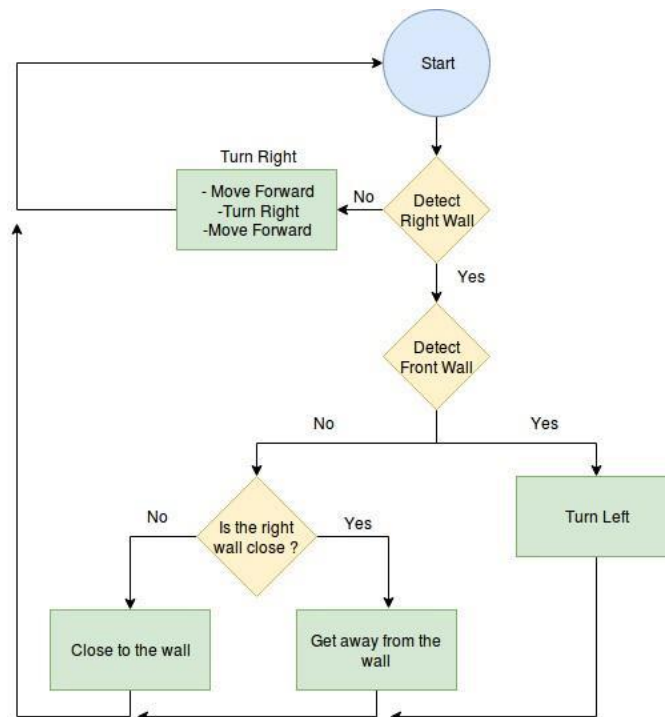
**Figure 8. Turn Right Sequence**

In addition, the robot must keep its distance from the wall when moving forward. This can be done by adjusting one motor to be faster or slower than the other.



**Figure 9. Collision Avoidance Algorithm**

The final state of the flow chart is shown in [Figure 10](#).



**Figure 10. Final Algorithm GreenPAK**

## 6. Design

The GreenPAK design consists of two parts. These are:

- Interpretation / processing of data from distance sensors ASM
- states and motor outputs

### 6.1 Interpretation / Processing of Data from Distance Sensors

It is important to interpret the data from the distance sensors. The robot's movements are deliberated according to the distance sensors outputs. Since the distance sensors are analog, we will use the ACMPs. The position of the robot relative to the wall is determined by comparing the voltages of the sensors with the predetermined threshold voltages.

We will use 3 ACMPs;

- To detect the front wall (ACMP2)
- To detect the right wall (ACMP0)
- To protect the distance of the right wall (ACMP1)

Since ACMP0 and ACMP1 depend on the same distance sensor, we used the same IN+ source for both comparators. Constant signal change can be prevented by giving ACMP1 25mv of hysteresis.

| A CMP0                                    |                      |         |  |
|-------------------------------------------|----------------------|---------|--|
| 100uA pullup on input:                    | None                 |         |  |
| Hysteresis:                               | Disable              |         |  |
| Low bandwidth:                            | Disable              |         |  |
| IN+ gain:                                 | Disable              |         |  |
| Connections                               |                      |         |  |
| IN+ source:                               | PIN 6                |         |  |
| IN- source:                               | 650 mV               |         |  |
| Information                               |                      |         |  |
| Typical ACMP thresholds                   |                      |         |  |
| V <sub>IH</sub> (mV)                      | V <sub>IL</sub> (mV) |         |  |
| 650                                       | 650                  |         |  |
| ACMP start time <a href="#">(Summary)</a> |                      |         |  |
| Min, us                                   | Typ, us              | Max, us |  |
| -                                         | 294.698              | 2736.73 |  |

| A CMP1                                    |                      |         |  |
|-------------------------------------------|----------------------|---------|--|
| 100uA pullup on input:                    | Disable              |         |  |
| Hysteresis:                               | 25 mV                |         |  |
| Low bandwidth:                            | Disable              |         |  |
| IN+ gain:                                 | x0.5                 |         |  |
| Connections                               |                      |         |  |
| IN+ source:                               | ACMP0 IN+ source     |         |  |
| IN- source:                               | 800 mV               |         |  |
| Information                               |                      |         |  |
| Typical ACMP thresholds                   |                      |         |  |
| V <sub>IH</sub> (mV)                      | V <sub>IL</sub> (mV) |         |  |
| 1625                                      | 1575                 |         |  |
| ACMP start time <a href="#">(Summary)</a> |                      |         |  |
| Min, us                                   | Typ, us              | Max, us |  |
| -                                         | 294.698              | 2736.73 |  |

| A CMP1                                    |                      |         |  |
|-------------------------------------------|----------------------|---------|--|
| 100uA pullup on input:                    | Disable              |         |  |
| Hysteresis:                               | 25 mV                |         |  |
| Low bandwidth:                            | Disable              |         |  |
| IN+ gain:                                 | x0.5                 |         |  |
| Connections                               |                      |         |  |
| IN+ source:                               | ACMP0 IN+ source     |         |  |
| IN- source:                               | 800 mV               |         |  |
| Information                               |                      |         |  |
| Typical ACMP thresholds                   |                      |         |  |
| V <sub>IH</sub> (mV)                      | V <sub>IL</sub> (mV) |         |  |
| 1625                                      | 1575                 |         |  |
| ACMP start time <a href="#">(Summary)</a> |                      |         |  |
| Min, us                                   | Typ, us              | Max, us |  |
| -                                         | 294.698              | 2736.73 |  |

Figure 11. ACMP's Settings

We can determine the direction signals based on the ACMPs' outputs. The circuit shown in [Figure 12](#) depicts the flow diagram outlined in [Figure 7](#).

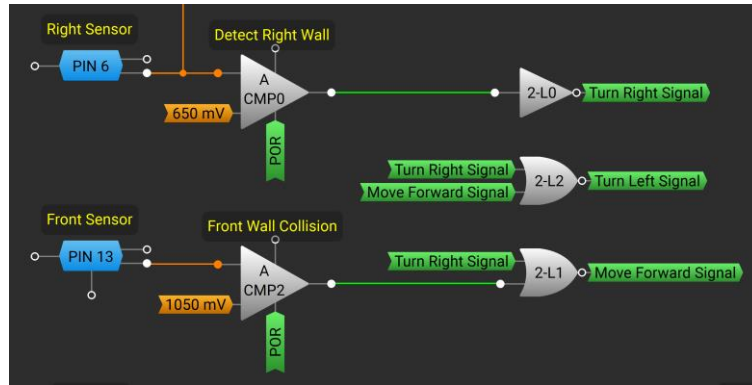


Figure 12. Wall Detection Circuit

In the same way, the circuit which indicates the position of the robot relative to the right wall is shown in Figure 13.

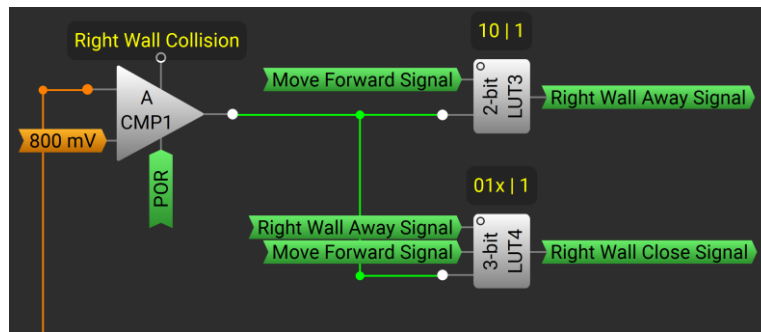


Figure 13. Wall Collision Circuit

## 6.2 ASM States and motor outputs

This application utilizes the Asynchronous State Machine, or ASM, to control the robot. There are 8 states in the ASM, and 8 outputs in each state. The Output RAM can be used to adjust these outputs. The states are listed below:

- Start
- Control
- Move away from the right wall
- Close to the right wall
- Turn Left
- Move Forward-1
- Turn Right
- Move Forward-2

These states determine the output to the motor driver and direct the robot. There are 3 outputs from the GreenPAK for each motor. Two determine the direction of the motor, and the other output determines the speed of the motor. The motor movement according to these outputs is shown in the following tables:

Table 1. Motor Movement According to Inputs

| IN1 | IN2 | Definition                      |
|-----|-----|---------------------------------|
| 0   | 0   | Motors remain off               |
| 0   | 1   | Motor rotates clockwise         |
| 1   | 0   | Motor rotates Counter-clockwise |
| 1   | 1   | Motors remain off               |

Table 2. PWM Table

| PWM | Definition |
|-----|------------|
| 0   | High Speed |
| 1   | Low Speed  |

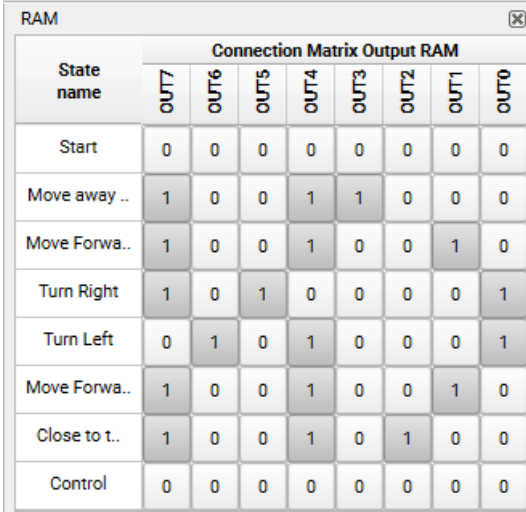
Table 3. Robot Movement According to Inputs

| M1-A | M1-B | M2-A | M2-B | Movement      |
|------|------|------|------|---------------|
| 0    | 0    | 0    | 0    | Stop          |
| 1    | 0    | 0    | 1    | Move Forward  |
| 0    | 1    | 1    | 0    | Move Backward |
| 1    | 0    | 1    | 0    | Turn Right    |
| 0    | 1    | 0    | 1    | Turn Left     |

Table 4. Robot Movement with PWM

| M1-A | M1-B | M2-A | M2-B | PWMA | PWMB | Movement                      |
|------|------|------|------|------|------|-------------------------------|
| 0    | 0    | 0    | 1    | 0    | 1    | Close to the right wall       |
| 1    | 0    | 0    | 1    | 1    | 0    | Move away from the right wall |

The ASM Output RAM is derived from these tables. It is shown in [Figure 14](#):



| State name    | Connection Matrix Output RAM |      |      |      |      |      |      |      |
|---------------|------------------------------|------|------|------|------|------|------|------|
|               | OUT7                         | OUT6 | OUT5 | OUT4 | OUT3 | OUT2 | OUT1 | OUT0 |
| Start         | 0                            | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Move away ... | 1                            | 0    | 0    | 1    | 1    | 0    | 0    | 0    |
| Move Forwa... | 1                            | 0    | 0    | 1    | 0    | 0    | 1    | 0    |
| Turn Right    | 1                            | 0    | 1    | 0    | 0    | 0    | 0    | 1    |
| Turn Left     | 0                            | 1    | 0    | 1    | 0    | 0    | 0    | 1    |
| Move Forwa... | 1                            | 0    | 0    | 1    | 0    | 0    | 1    | 0    |
| Close to t... | 1                            | 0    | 0    | 1    | 0    | 1    | 0    | 0    |
| Control       | 0                            | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

Figure 14. Connection Matrix Output RAM

In addition to the motor drivers there are two more outputs. These outputs go to the corresponding delay blocks to allow the robot to travel a certain distance.



PWMs were used to adjust the speed of the motors. The ASM was used to determine what PWM the motor would run on. The PWMA-S and PWMB-S signals are set to the mux select bits.

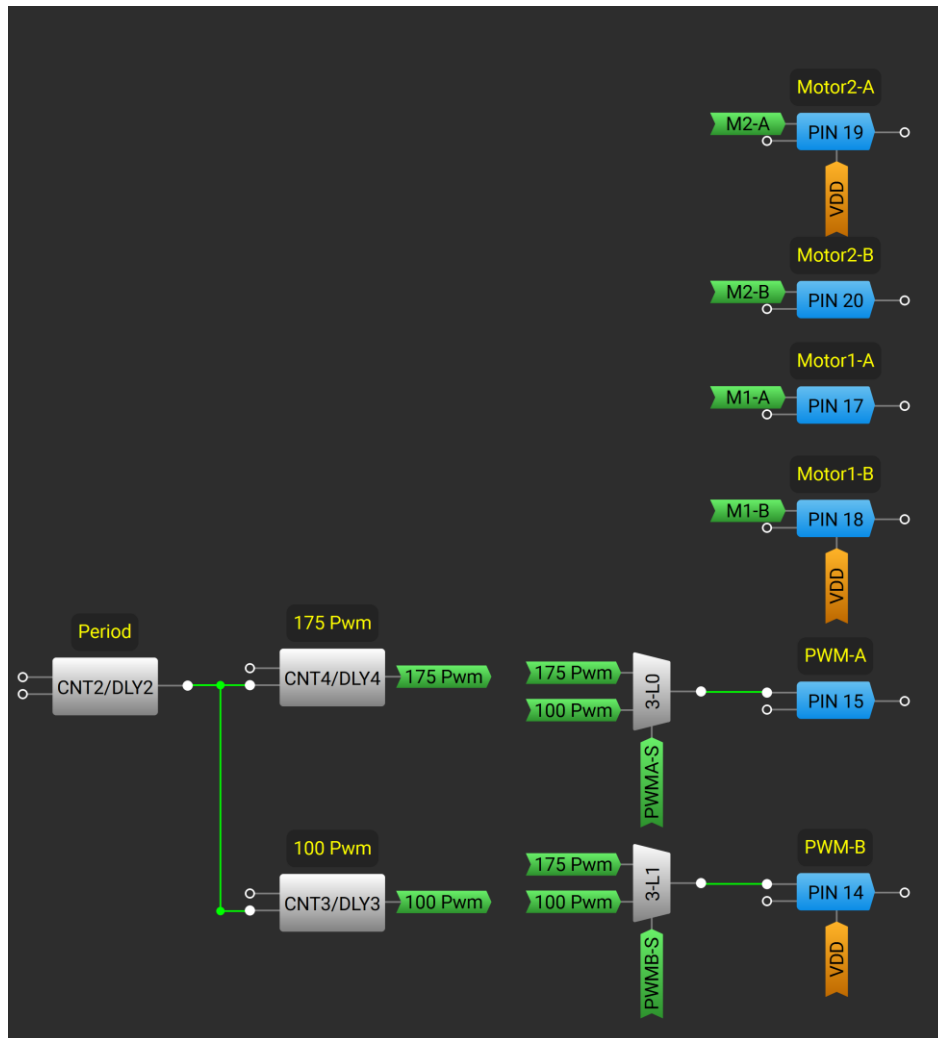


Figure 17. Motor Outputs

## 7. Conclusion

In this project, we used a GreenPAK SLG46531V to create a maze-solving robot. We interpreted data from multiple sensors, controlled the robot's state with the GreenPAK's ASM, and drove the motors with a motor driver. Generally, microprocessors are used in such projects, but a GreenPAK has a few advantages over an MCU: it is smaller, more affordable, and can process the sensor output faster than an MCU.

## 8. Revision History

| Revision | Date              | Description                                                   |
|----------|-------------------|---------------------------------------------------------------|
| 1.00     | November 16, 2017 | Initial release.                                              |
| 2.00     | May 5, 2026       | The part number has been changed from SLG46531V to SLG46537V. |

## IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES ("RENESAS") PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD-PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers who are designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only to develop an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third-party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising from your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Disclaimer Rev.1.01)

### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

### Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit [www.renesas.com/contact-us/](http://www.renesas.com/contact-us/).

### Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.