Application Note

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

AN-CM-249

Abstract

This application note focuses on creating an accurate bike speedometer using a GreenPAK™ IC and a magnetic sensor. Two methods are used to approach this application: the first uses the frequency detect blocks of the SLG46536V, the second method uses an RPM counter design. The nominal resolution of this application is 1 m/s but can be changed depending upon the number of magnets used on the wheel.

This application note comes complete with design files which are listed in the References section.

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Contents

Figures

Tables

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

1   Terms and Definitions

CLK	Clock
CNT	Counter
IC	Integrated circuit
LED	Light-emitting diodes
MCU	Microprocessor control unit
OSC	Oscillator
RPM Counter	Revolutions per minute counter

2   References

For related documents and software, please visit:

https://www.dialog-semiconductor.com/products/greenpak.

Download our free GreenPAK™ Designer software [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 Electronics provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the IC.

[1]   GreenPAK Designer Software, Software Download and User Guide, Renesas Electronics

[2]   AN-CM-249 Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor.gp, GreenPAK Design File, Renesas Electronics

[3]   GreenPAK Development Tools, GreenPAK Development Tools Webpage, Renesas Electronics

[4]   GreenPAK Application Notes, GreenPAK Application Notes Webpage, Renesas Electronics

[5]   SLG46536V, Datasheet, Renesas Electronics

[6]   Axial Lead Reed Switches, Datasheet, Littelfuse

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

3   Introduction

This application note explores designing a speedometer to measure and display the speed of a bicycle wheel using a magnetic sensor. The system should be able to interpret measurement in meters per second. To achieve this system, a sensor device is attached to the bicycle. The GreenPAK design then performs logical operations to update the output periodically, or simultaneously, to interpret measurement results using four binary digits. This application is designed to be precise up to 1 m/s.

The input of the system is a digital signal from a magnetic switch. The magnetic switch is used because, though both magnetic and optical sensors are known to be used in tachometers, magnetic switches are favorable for applications that have ambient light. This is critical for a solution that can be easily-affixed to a bicycle. In this application, every full rotation of the wheel represents 2 meters traveled (roughly the circumference of the wheel).

This application note describes two designs, both of which have their pros and cons. The first design utilizes the frequency detector of the SLG46536 to determine the rotational speed of the bike. The second uses the typical RPM method of incrementing the number of pulses (full rotations) over a given period.

The key advantages to using GreenPAK are that it is smaller, lower cost, simpler, and easier to develop than most other solutions. Furthermore, the GreenPAK design for the bike speedometer can be modified into complicated projects, such as the internal speedometer for an electric bike or a moped. A microcontroller could be used instead, but the size and power consumption of the microcontroller can make it less appealing to a customer.

The system can be tested by inspecting the digital output signal. For this application, we use between four and six LEDs for visual representation of the data. Each LED represents a single bit of a binary sequence. The application has been tested by comparing the digital output of GreenPAK to various radial speeds of a wheel. To show this solution is appealing for the biking industry we can evaluate dimension, development capability, and other parameters of comparison.

Creating a Bike Speedometer with GreenPAK and a
Magnetic Sensor

4   First Design: Frequency Detector

In terms of components, the SLG46536 is one of the more complex GreenPAK ICs with a large number of counter/delay/frequency detector blocks. The frequency detector of the counter blocks acts like a frequency filter and can be configured by set counter data. From the counter data, a signal is generated that determines if the incoming pulses occur more or less frequently than the given period. For this IC, there are 8-bit and 16-bit frequency detectors. The 16-bit frequency detectors generate more precise measurements. This application uses both types.

If the input frequency of the block is higher than the configured frequency, the frequency block will output a digital high. Two 16-bit CNT blocks, utilized as a frequency detector, are shown in Figure 1.

Figure 1: Frequency Detector Configuration for Speed 1 m/s (Left Side) and 2 m/s (Right Side)

The application's wheel circumference is 2.06 m. When the wheel of the bike rotates at least once in 2.060 s, the horizontal speed of the bike is more than 1 m/s. Because of that, the counter data is set to 803 with clock source OSC0 CLK/64. Using these calculations, the period of the block is 2.05824 s, as this is the closest configurable value to 2.060 s.

Similarly, to configure the second frequency detector to detect speeds of more than 2 m/s, the wheel of the bike should rotate at least once in 1.030 s. The counter data is therefore set to 401 with clock source OSC0 CLK/64, to make the period of the block 1.02912 s. This methodology will be implemented for the other speeds, that is, 3 m/s to 7 m/s, for a single IC in this application. The output of each frequency detector is given in Table 1.

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Table 1: Frequency Detector Output

Speed (m/s)	Frequency Detector Output
1	1000000
2	1100000
3	1110000
4	1111000
5	1111100
6	1111110
7	1111111

To measure more than 7 m/s another IC can be added. The maximum speed is then 14 m/s. This speed is fast enough for a bike.
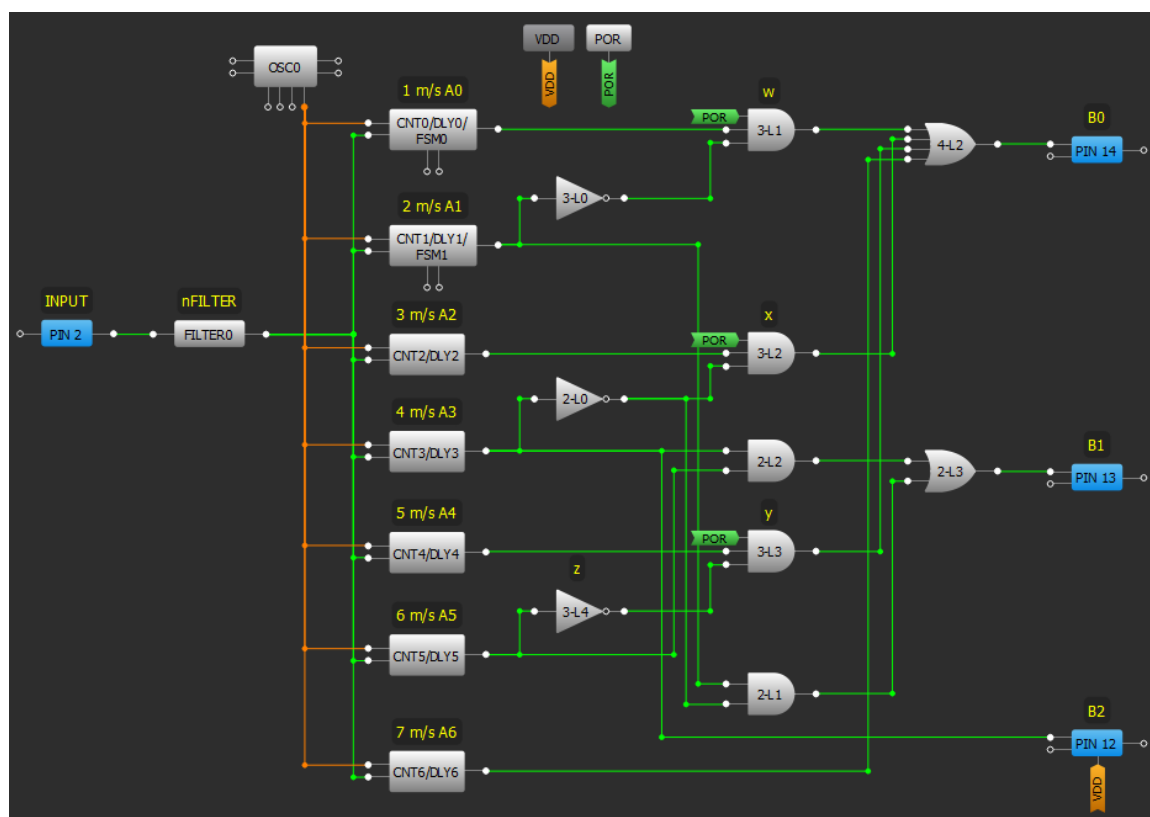

Figure 2: GreenPAK Design for First Method with Measurement Range 0 to 7 m/s

Every 1 m/s increase in speed uses one counter block for detection. So, with only one IC, a maximum 7 m/s with a resolution of 1 m/s can be measured. The digital circuit on this design converts the frequency detector output bits (from Table 1) to a 3-bit binary sequence, which is output on B2:B0.

Table 2: Input (Frequency Detector Output) and Output of Digital Circuit

Speed (m/s)	Frequency Detector Output	Expected Output B
1	1000000	001
2	1100000	010
3	1110000	011
4	1111000	100

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Speed (m/s)	Frequency Detector Output	Expected Output B
5	1111100	101
6	1111110	110
7	1111111	111

Table 3: Configuration Table Using GreenPAK for 1 m/s to 7 m/s

Speed (m/s)	Output B	Period Expected (ms)	Clock Source	Counter Data	Period Implemented (ms)
1	001	2060	OSC0 CLK/64	803	2058.24
2	010	1030	OSC0 CLK/64	401	1029.12
3	011	686.67	OSC0 CLK/64	255	655.36
4	100	515	OSC0 CLK/64	200	514.56
5	101	412	OSC0 CLK/64	160	412.16
6	110	343.33	OSC0 CLK/64	133	343.04
7	111	294.29	OSC0 CLK/64	114	294.40

4.1 Extended Version of Speedometer with Speed Range up to 14 m/s

In the previous design, the maximum speed is only up to 7 m/s. Adding a second IC scales the maximum speed up to 14 m/s. Figure 3 shows a GreenPAK design and configuration that has been implemented with the SLG46536V.
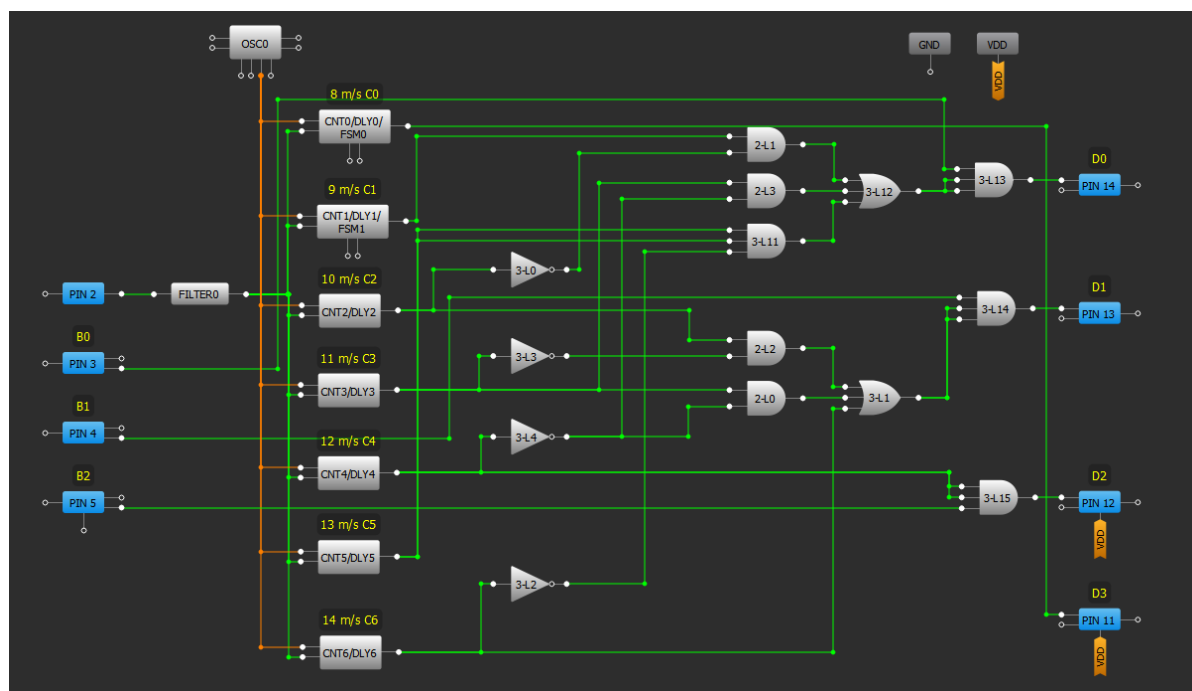

Figure 3: GreenPAK Design to Extend the First Method with a Range of 8 m/s to 14 m/s

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Table 4: Configuration Table Using GreenPAK for 8 m/s to 14 m/s

Speed (m/s)	Output B	Period Expected (ms)	Clock Source	Counter Data	Period Implemented (ms)
8	1000	257.5	OSC0 CLK/24	267	257.28
9	1001	228.89	OSC0 CLK/24	237	228.48
10	1010	206	OSC0 CLK/24	214	206.40
11	1011	187.27	OSC0 CLK/24	194	187.20
12	1100	171.67	OSC0 CLK/24	178	171.84
13	1101	158.46	OSC0 CLK/24	164	158.4
14	1110	147.14	OSC0 CLK/24	152	146.88

Overall, the design for the extended IC is similar to the main IC. However, the output of the main IC is also an input of the extended IC. The overall system using two ICs for this application is shown in Figure 4.
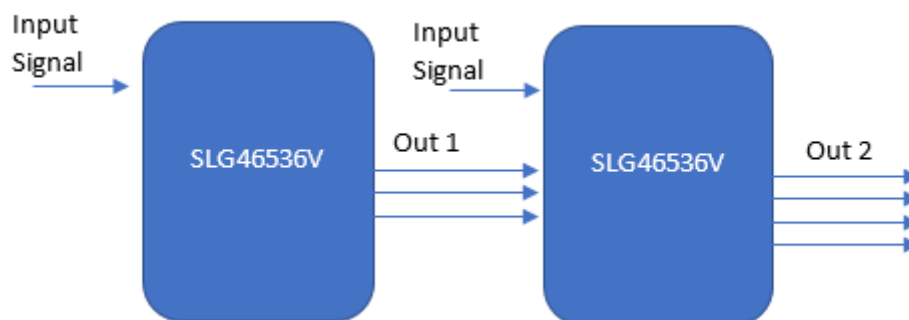

Figure 4: System Diagram of Frequency Detector with Two ICs

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5   Second Design: RPM Counter

The second design is a very different method of reading speed than the first. This design uses a full-adder digital circuit. Every rotation of the wheel increments the counter by one. The counter resets after a given period of time. This design uses 2.06 s as the period; this also becomes the refresh-rate of the measured result. So, if there is only one rotation in 2.06 s, the bike's speed is only 1 m/s. If there are two rotations in 2.06 s, the bike's speed is 2 m/s, and so on.
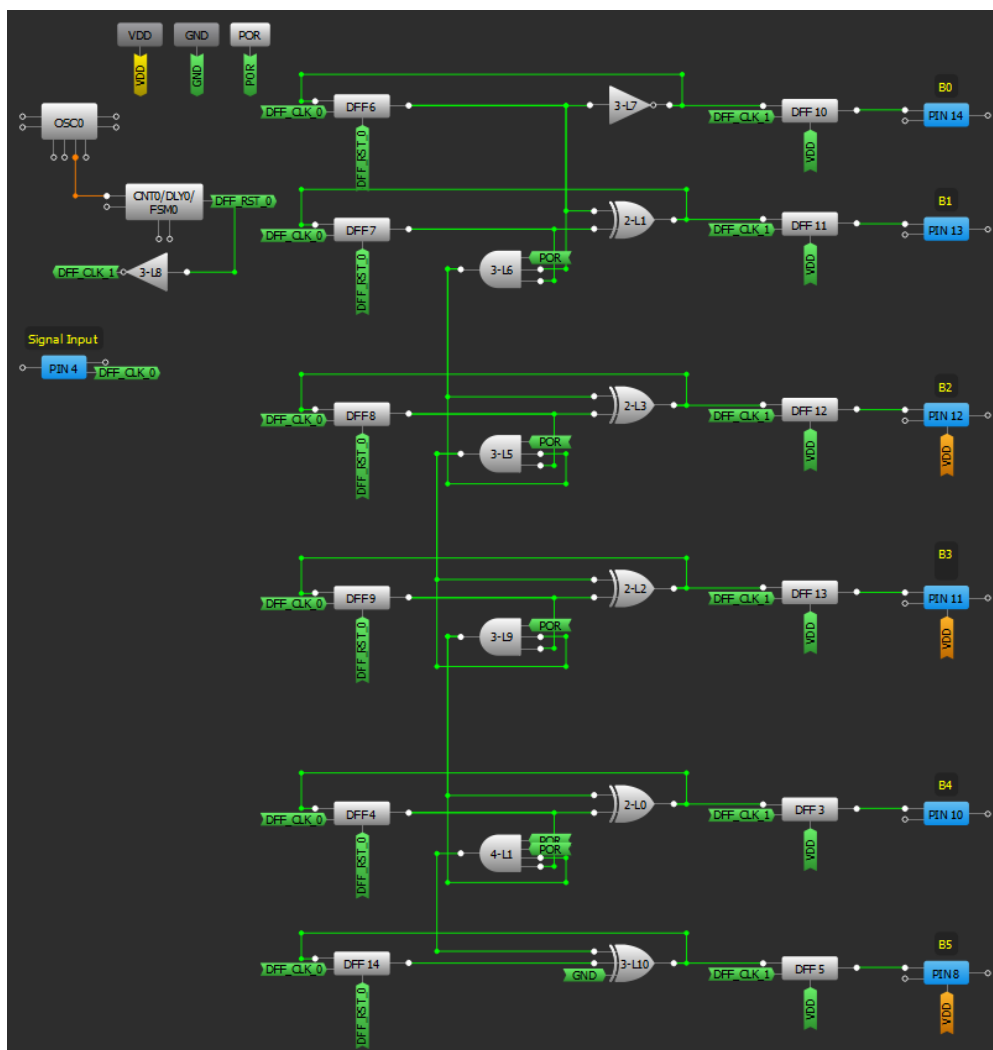

Figure 5: GreenPAK Design Using RPM Counter

In this design, the maximum speed can be measured up to 63 m/s (6-bit output). It is possible to optimize this method based on requirements. For example, the measurement accuracy can be improved to 1 km/h; the output will update for every 2.06 x 3.6 = 7.42 s. Since this refresh rate would be unusable for many applications, another option would be to improve the accuracy up to 2 km/h and update the output every 3.71 s. So, the measurement result is multiplication of 2 km/h such as 2, 4, 6, 8, 10, and so on. The design can also be implemented with a 3 km/h accuracy and update the output every 2472 ms. The system diagram of this method is illustrated in Figure 6.
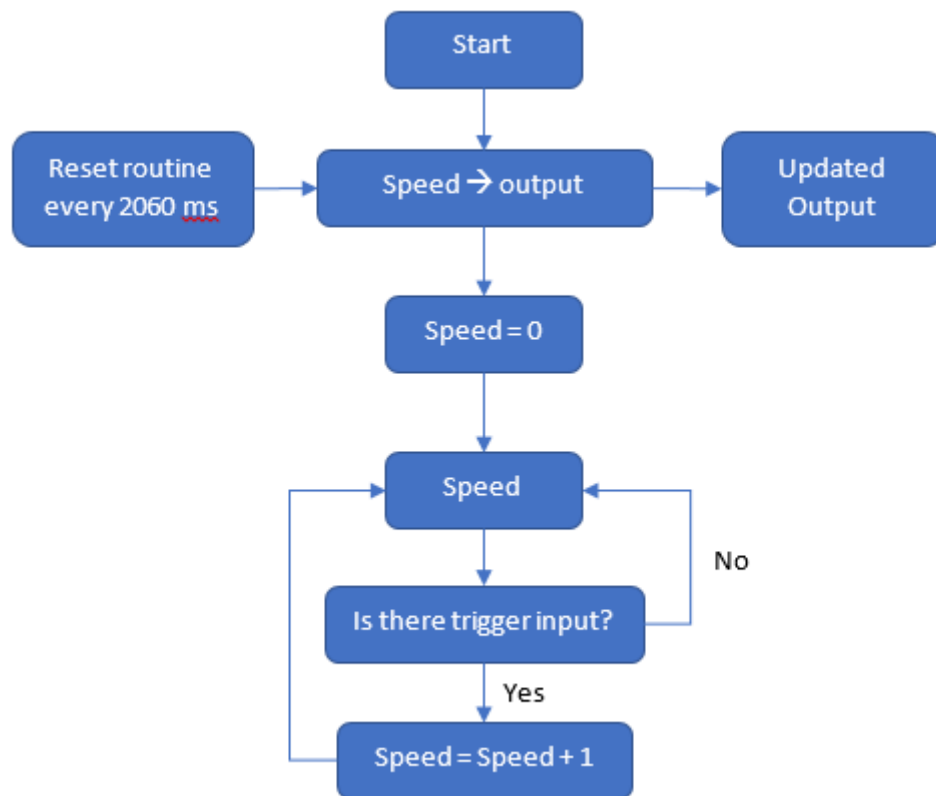
Figure 6: System Diagram for RPM Counter Method

The simplest method to improve accuracy would be to have more than one magnet on the wheel; this would ensure multiple pulses per rotation and would give better resolution in RPM.

6 Results

There are two possible designs for comparison.

Table 5: Designs for comparison

Design Approach	Detail	Measurement Update	Speed Range
1	Frequency detect	Real time	0 m/s to 7 m/s for each IC
2	RPM counter	Every 2.06 s	0 m/s to 63 m/s for each IC

In most circumstances, the second design is a better application, so the results focus on the second design using the RPM counter.
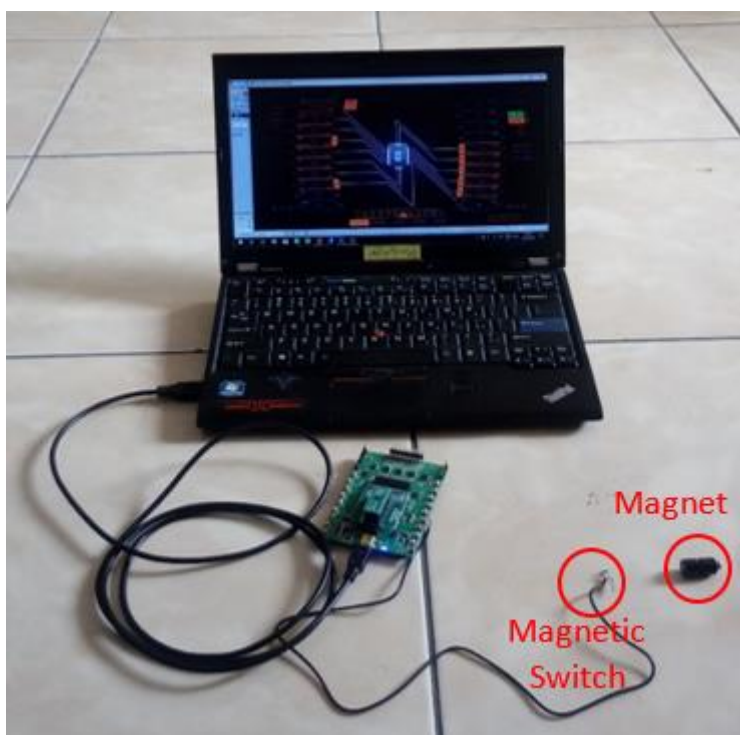

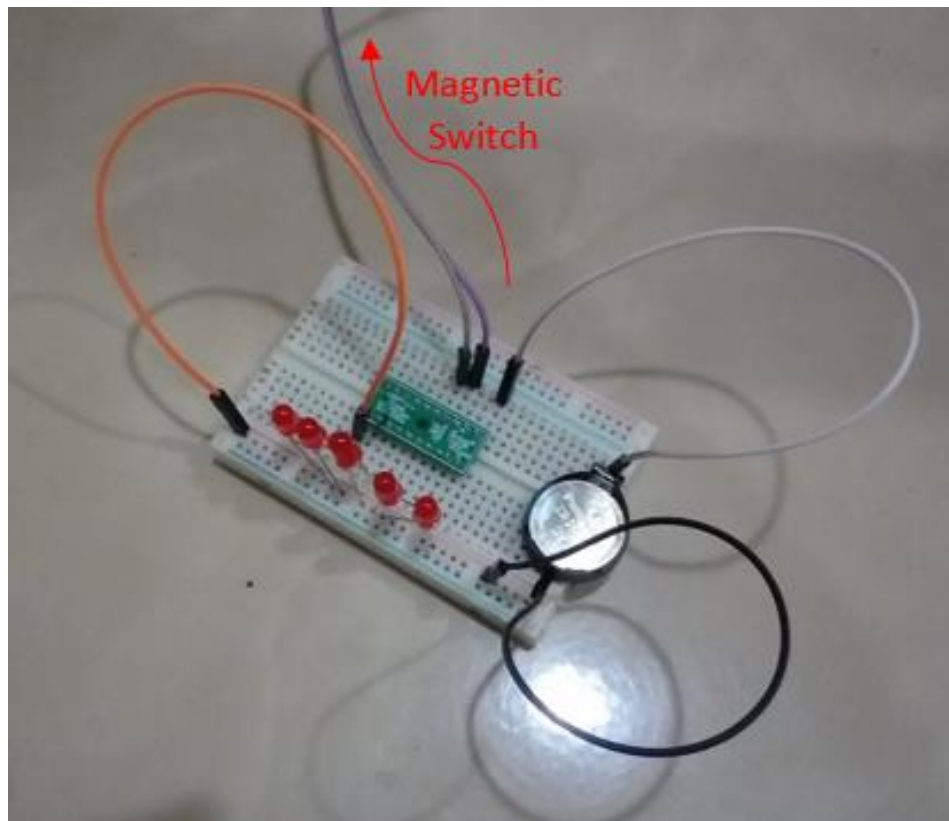**Figure 7: Simulate Circuit Design Using a Renesas Development Board**

Figure 8: Prototype Circuit Using LED for 5-bit Output

Figure 9: Magnet and Magnetic Switch Attached to Bicycle

The back wheel of the bicycle is used to test the speedometer designs. The measurement results for each wheel speed are given below. There are five LEDs. The most significant bit (MSB) is interpreted by the LED on the left side.

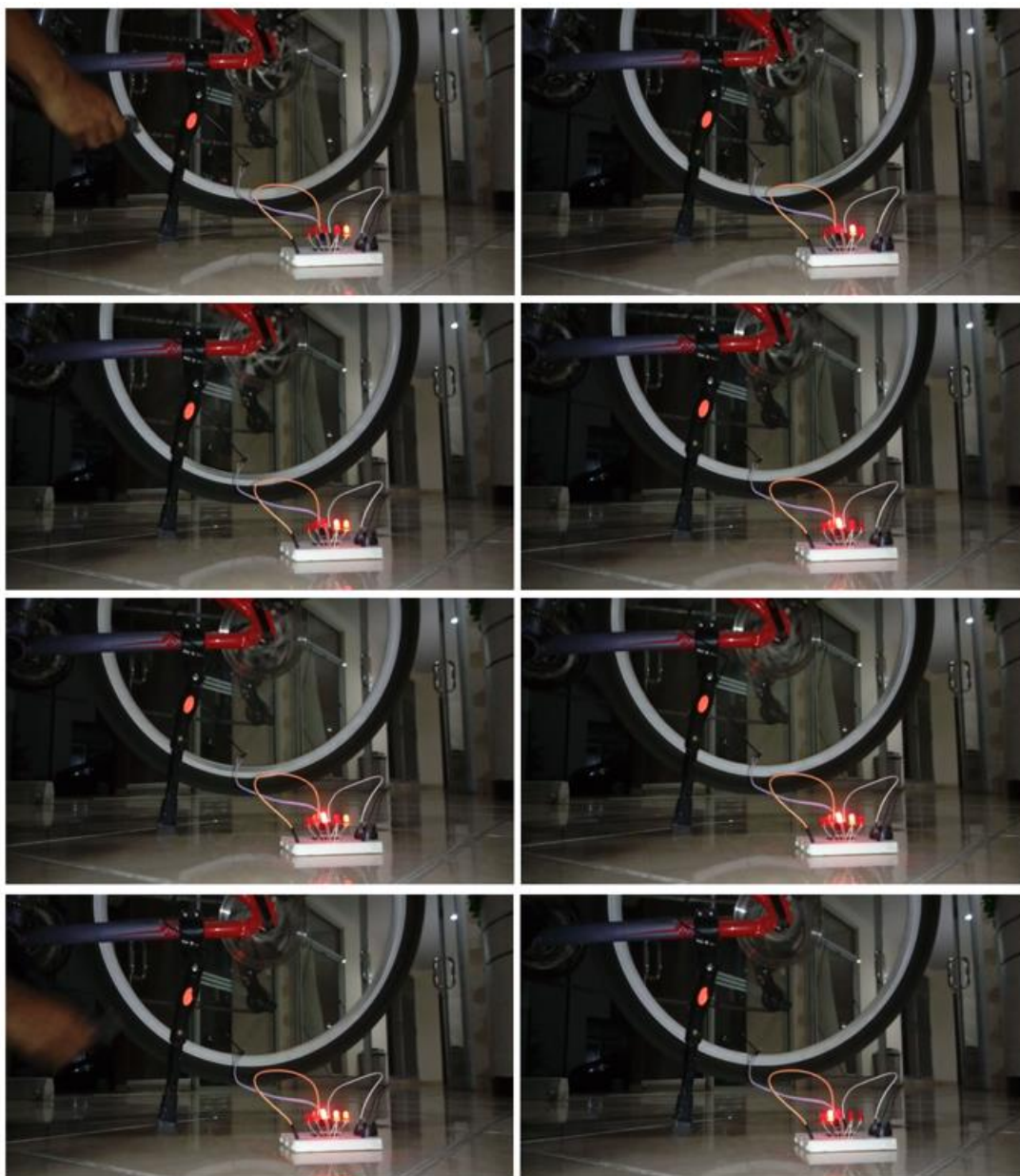# Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Figure 10: LED Output

Figure 10 shows the results for the first 4 bits (up to 7 m/s), where the design was able to output the binary value of the bike's velocity.

An alternative solution to using GreenPAK would be to use a small microcontroller, such as an ATtiny85. However, using an MCU has its own disadvantages such as knowing how to program it, which programming environment to use, and increased cost and size, see Table 6.

Table 6: Comparison to Competing Solution with Reference to each Datasheet

Indicator	Renesas Product	ATtiny85
Minimum dimension (mm)	1.95 x 1.55 x 0.50	7.7 x 5.13 x 1.7
Programming requirement	No	Yes
Power consumption typical	1.8 V and 260.15 µA 5 V and 697.94 µA	1.8 V and 300 µA
Price	USD 0.5	USD 1.58 (element14.com)
Adjustable	Yes	Yes

7   Conclusion

This application note outlined how to create a simple bike speedometer with a GreenPAK SLG46536V. The rotational speed of the bicycle wheel was measured with a magnetic sensor. Two approaches to solving the problem were demonstrated – a frequency method and an RPM method. The RPM counter could also be used for other applications such as anemometers, tachometers, and so on.

Creating a Bike Speedometer with GreenPAK and a Magnetic Sensor

Revision History

Revision	Date	Description
1.0	03-Aug-2018	Initial version.

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