Application Note

Smart Lock Motor Driver with Voltage Regulation

AN-CM-296

Abstract

This application note describes GreenPAK, configured as a Brushed DC motor driver with constant voltage regulation and motor on/off control by current sensing.

The application note comes complete with design files which can be found in the Reference section.

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1 Terms and Definitions

DC	Direct current
PWM	Pulse width modulation
CMP	Comparator
CCMP	Current comparator
MCU	Microcontroller unit
HV	High voltage
GPO	General purpose output

2 References

For related documents and software, please visit:

GreenPAK™ Programmable Mixed-Signal Products | Renesas

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. Find out more in complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the GreenPAK IC.

[1] Go Configure™ Software Hub | Renesas, Software Download and User Guide

[2] AN-CM-296 Smart Lock Driver with Voltage Regulation.gp , GreenPAK Design File

[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage

[5] SLG47105 Datasheet

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3 Introduction

Many smart locks use additional mechanical or electrical components to determine whether a deadboltis open or closed. It might be simple switches, or hall sensors with magnets, or an encoder. The design in this application note doesn't require any such additional components. The motor driver turns off the motor when deadbolt reaches open or closed state by motor current sensing.

Many smart locks use four AA batteries for power supply. In this case, the power supply voltage decreases from 6.5 V (charged batteries, 1.63 V each) to 3.6 V (discharged batteries, 0.9 V each) and the motor rotates with different speeds at 6 V and 3.6 V. Also, higher voltage might burn out the motor.

In this application note, voltage regulation is used. The motor is controlled by PWM. When batteries are fully charged, the PWM duty cycle is approximately 50%, and increases while battery is discharging, so the regulated voltage stays unchanged.

Figure 1. Motor

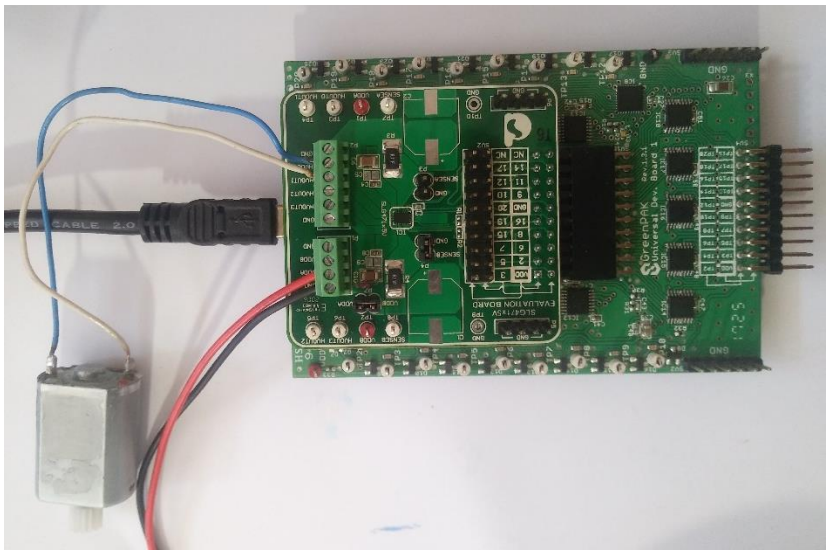

Figure 2. Hardware Connection Photo

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4 Construction and Operation Principle

This typical Application circuit requires only one external component – a current sense resistor.

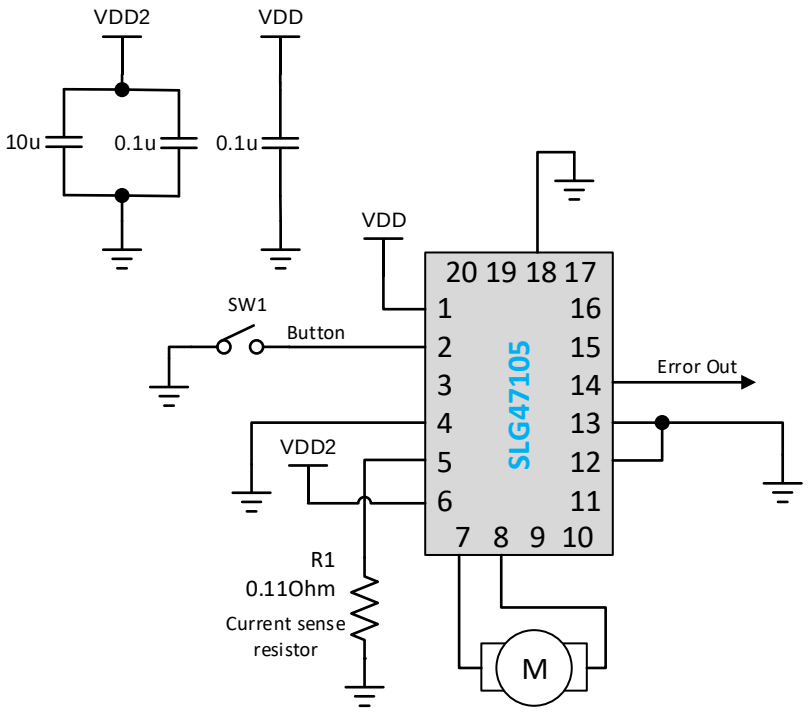

Figure 3. Typical Application Circuit

The design has one input for driver control and another one for fault monitor:

PIN#2 – a Button for close/open the smart lock deadbolt.

PIN#14 – Error output. When the closing time is less than 1 Second (can't close smart lock), this output goes HIGH.

The general block diagram is shown in Figure 4.

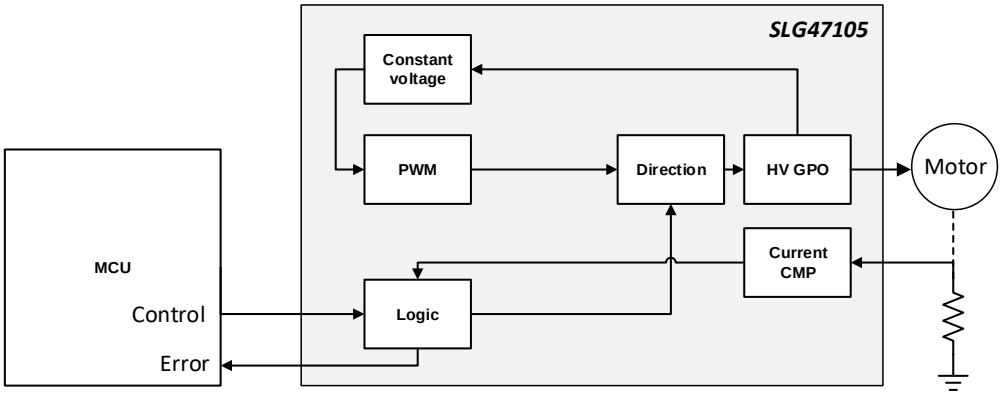

Figure 4. Block Diagram

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4.1 Normal Operation

The smart lock is opened by a falling edge on PIN2 and is closed by a rising edge.

During the first 150ms, an internal circuit ignores the CCMP0 signal because during this time the starting current of motor is higher than at normal operation. After that, during normal operation, if motor current increases to 290 mA, the motor turns off.

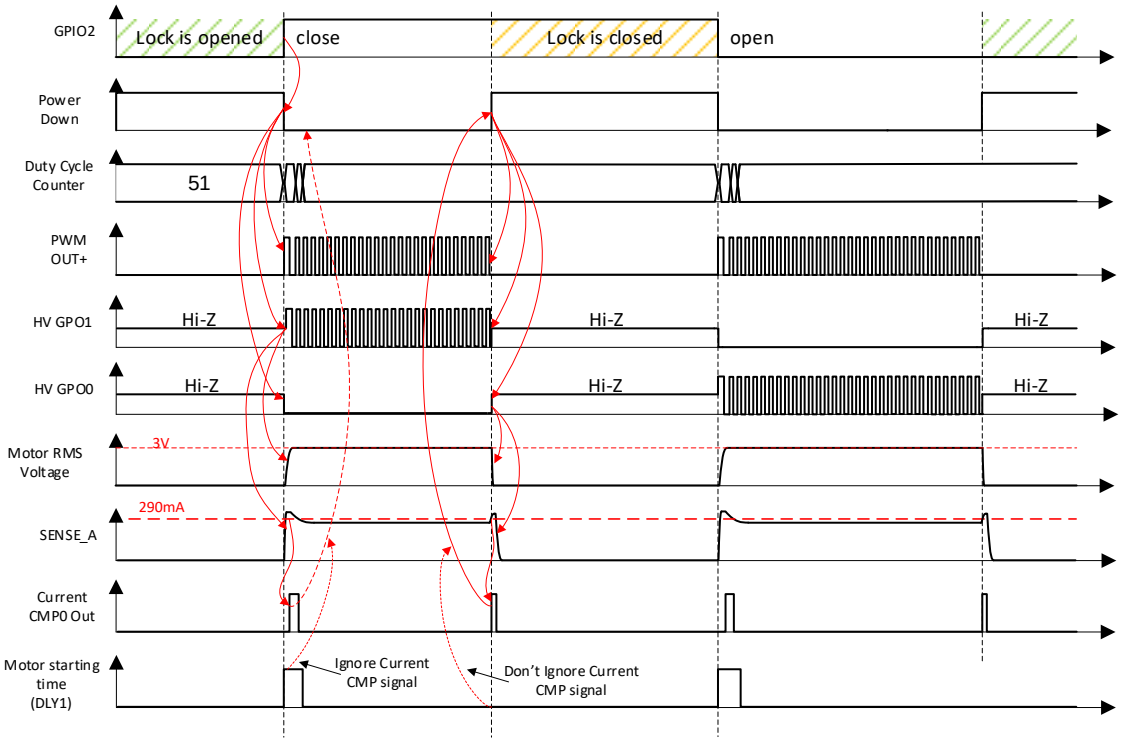

Figure 5. Normal Operation

A rising edge at PIN2 turns on the motor. The PWM duty cycle is changing depending on the power supply voltage. For example, at 6V the duty cycle value is at 50%. When batteries discharge to 3.6 V, the PWM duty cycle increases to approximately 83%. This behavior provides a constant level of the motor supply voltage at 3 V (regulated value), see Figure 6.

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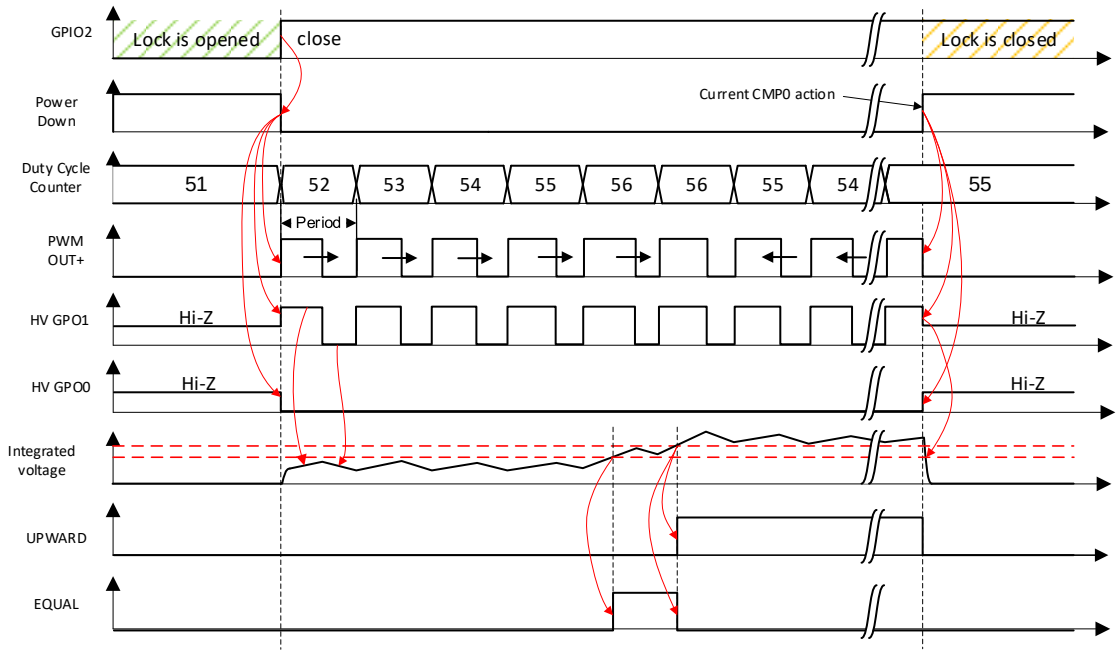

Figure 6. Voltage Regulation

4.2 Changing of the Control Signal During Operation

In addition, this design permits changing deadbolt direction during the opening or closing process. This can be useful in the case when the user changes his mind and wants to open the door after pressing the close button, see Figure 7.

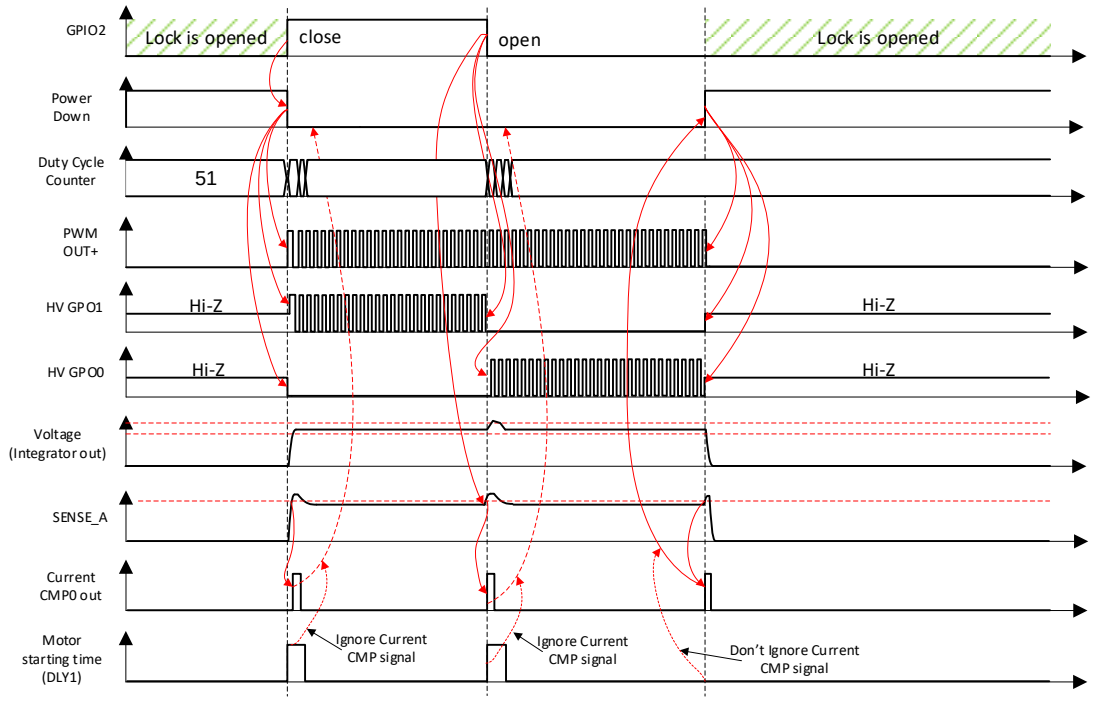

Figure 7. Changing Control Signal During Operation

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4.3 Error Closing

The Error Output can be used to detect an event when the door can't be closed. In our case the closing time is equal to 1 second and can be changed in a wide range.

When the closing time is less than 1 second, the Error Output goes HIGH. It will be reset after the next falling edge at PIN2.

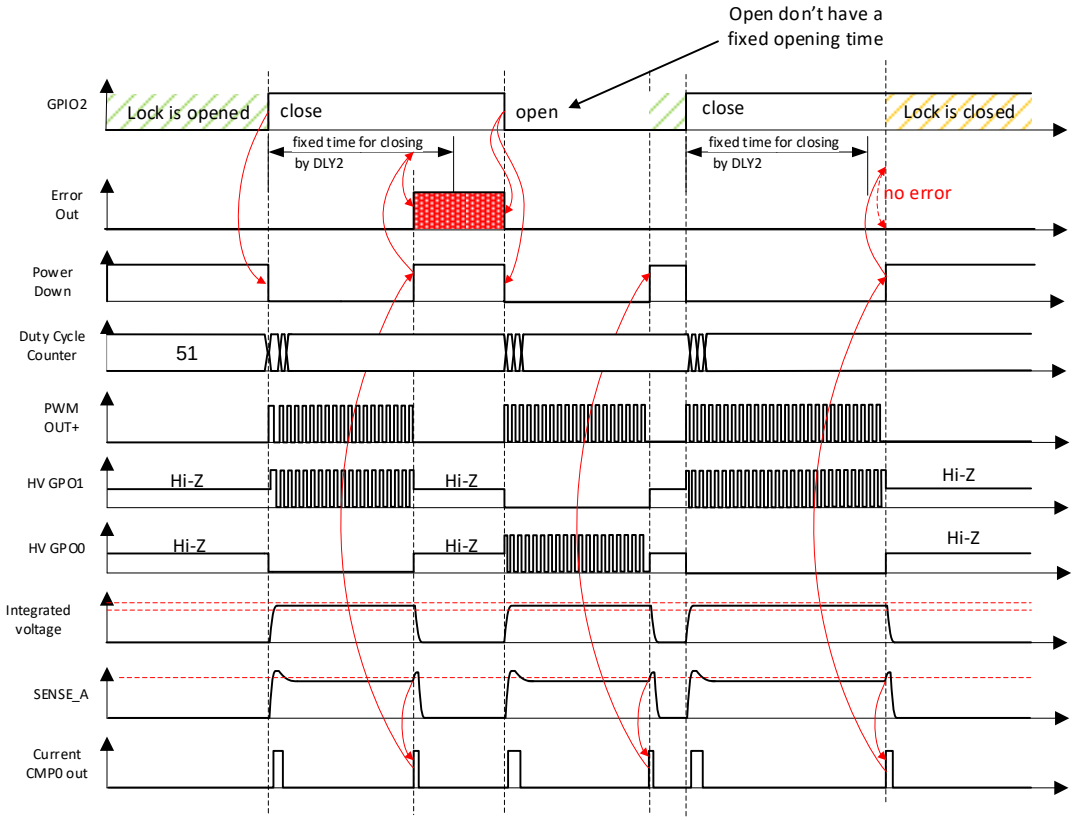

Figure 8. Error Closing

5 Motor Parameters Measurement

Two parameters need to be measured to adjust the timings and control the circuit used in our design: motor starting time and motor current consumption.

Motor starting time is approximately 100 ms.

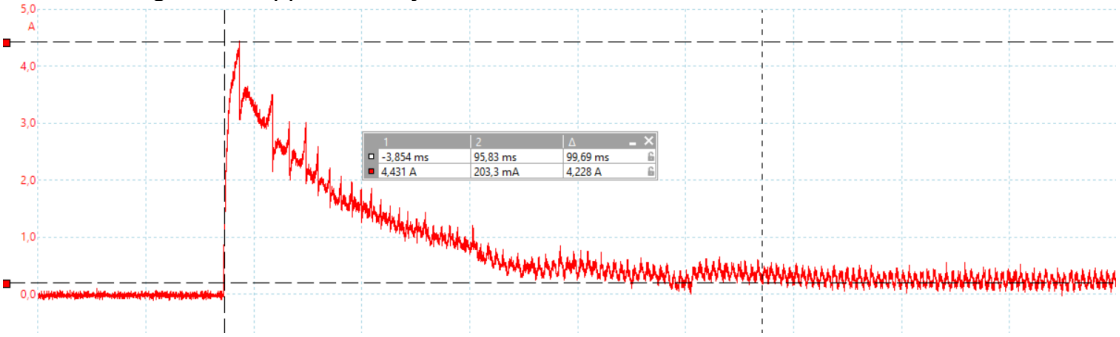

Figure 9. Motor Starting Current, 3 V Power Supply

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There is a lot of noise and our circuit will provide filtration where needed. The maximum value of the motor current consumption is 310 mA at 3 V power supply. RMS current is approximately 208 mA.

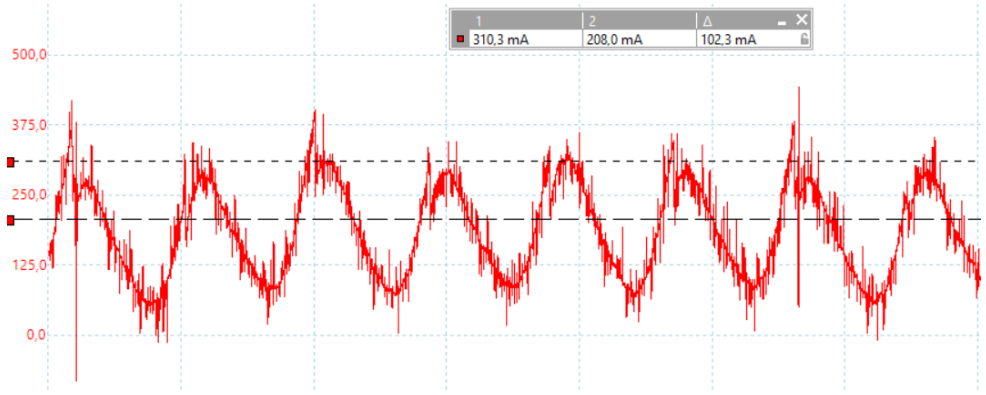

Figure 10. Motor Normal Operation Current, 3 V Power Supply

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6 GreenPAK Design

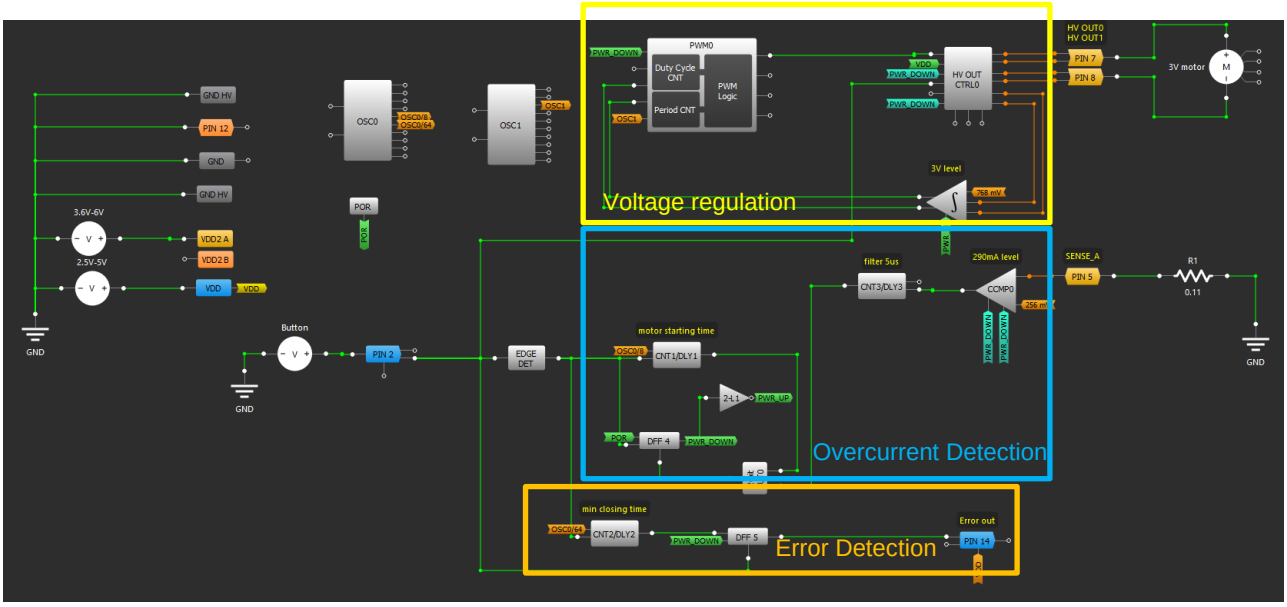

Figure 11. Design View

6.1 Voltage Regulation

Voltage regulation is done by using PWM and Diff.Amp&Integrator blocks. Diff.Amp&Integrator Vref has an internal divide by 4:

Vref = Vdesired*Gain = 3 V * 0.25 = 0.75 V

where:

Vdesired – desired constant voltage for motor power supply;

Gain – internal Diff.Amp&Integrator gain is constant - 0.25.

Then the closest value from Vreg list is 0.768 V.

The Diff.Amp&Integrator outputs are connected to PWM block to increase and decrease the duty cycle depending on the measured voltage. When batteries are fully charged, the PWM duty cycle is 50% and more than 80% when batteries are discharged.

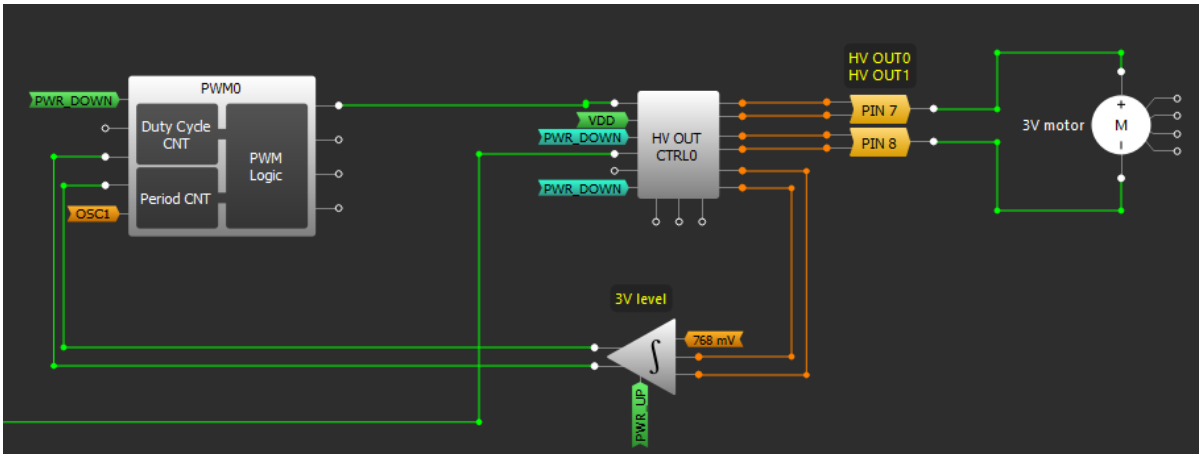

Figure 12. Voltage Regulation

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6.2 Overcurrent Detection

The overcurrent detection starts after delay (selected by DLY1) because when the motor is starting up, there is a current spike, see Figure 9. After that, the motor automatically turns off when the voltage drop across resistor R1 is higher than CCMP0 Vref value. DLY3 block is used to filter spikes and noise caused by the motor running.

CCMP0 Vref value is defined by the next equation:

Vref = Ipeak* Rsense * Gain = 0.3 A * 0.11 Ohm * 8 = 0.264 V

where:

Ipeak – peak motor current at normal operation, see Figure 10;

Rsense – sense resistor value;

Gain – current CMP gain, can be selected by register 8 or 4.

The closest value is 256 mV and 288 mV. Selected value is 256 mV to speed-up motor stall detection and decrease battery discharging.

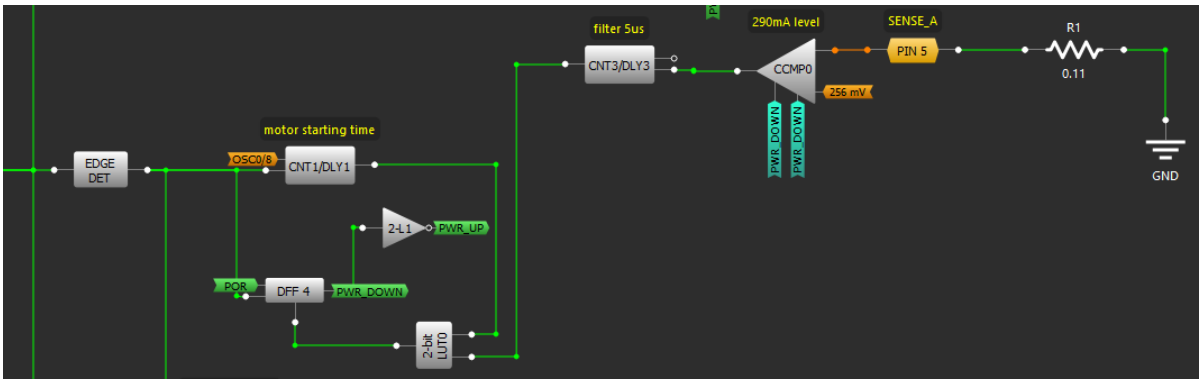

Figure 13. Overcurrent Detection

6.3 Error Detection

An error means that the smart lock can't close the deadbolt because it is stopped by some obstacle and the door cannot close completely. In this case, the time between motor turn on and automatically turn off will be shorter than in normal operation. An Error Out can detect this situation. It will be HIGH when the closing time is shorter than the selected value in DLY2.

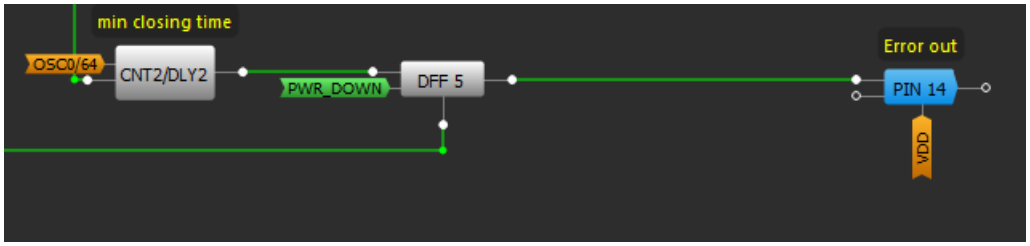

Figure 14. Error Detection

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7 Waveforms

7.1 Voltage Regulation

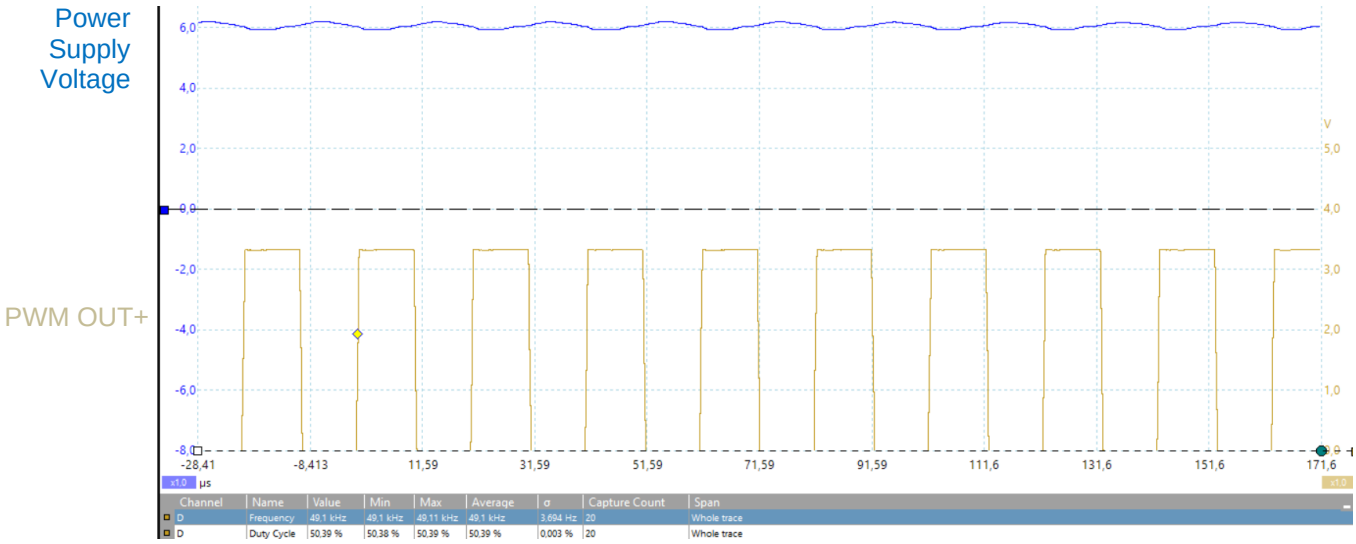

Figure 15. PWM Duty Cycle 50% at 6 V Power Supply

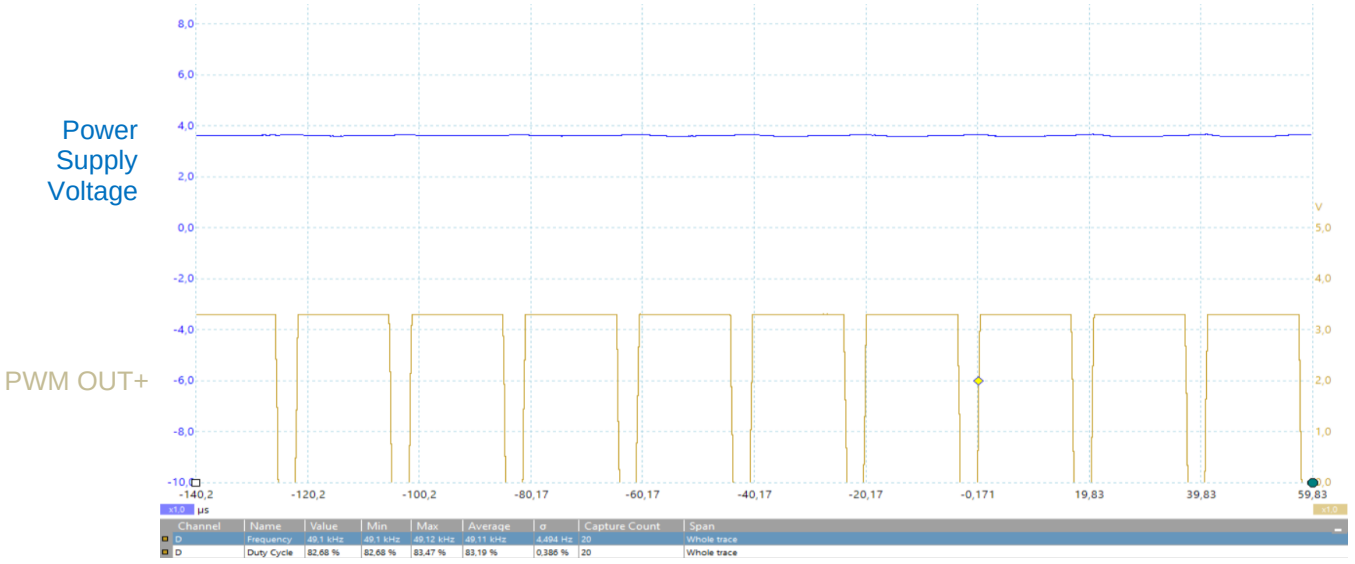

Figure 16. PWM Duty Cycle 82% at 3.6 V Power Supply

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7.2 Auto Turn Off Motor

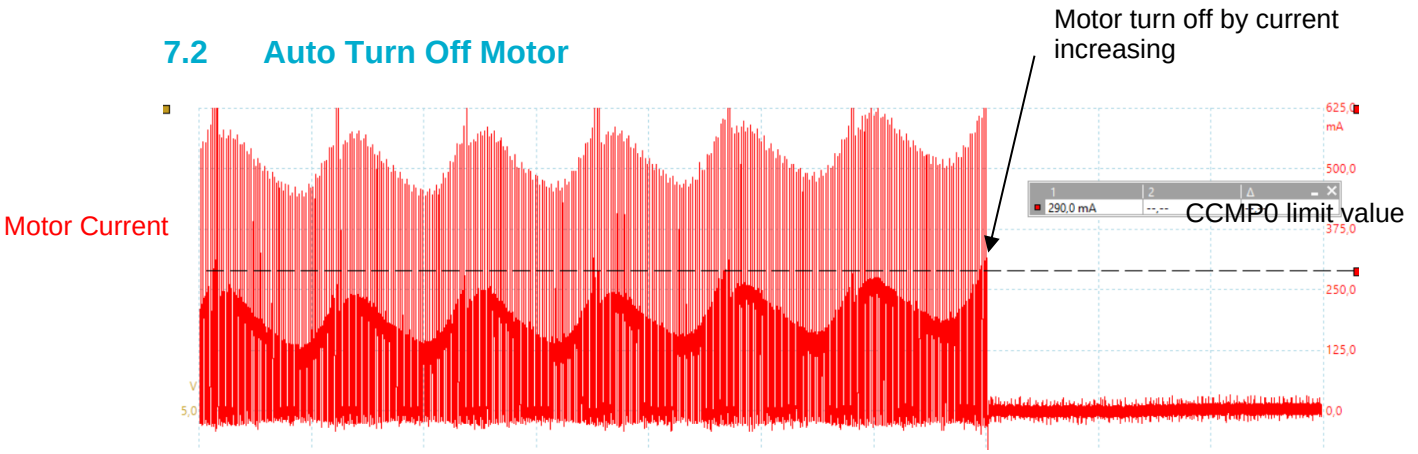

Figure 17. Motor Turn Off by Current Increasing, 6 V Power Supply

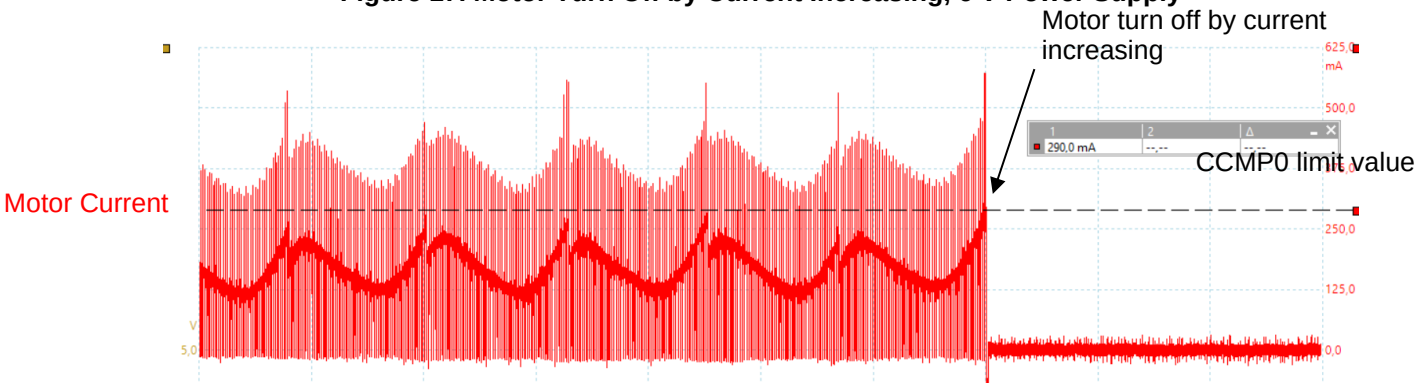

Figure 18. Motor Turn Off by Current Increasing, 3.6 V Power Supply

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8 Conclusion

The application note describes how to configure the SLG47105 IC to control a Brushed DC motor. Embedded into the SLG47105, a “Differential Amplifier with Integrator and Comparator” macrocell is used for Motor Voltage Regulation. It is used to drive a motor with nominal voltage lower than the power supply voltage. Also, “Current Comparator” macrocell is used to automatically turn off the motor when a current threshold is reached.

The motor control logic can be customized for specific user requirements. Also, this design can be used with a higher-powered motor with nominal current up to 2 A. In this case, HV GPOs should be connected in parallel according to the Datasheet [5].

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Revision History

Revision	Date	Description
1.0	02-Jun-2020	Initial version

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