Rechargeable Electric Screwdriver
SLG47105

This application note describes how to create a Rechargeable Electric Screwdriver using HVPAK SLG47105. The device is powered by a 3.7 V Li-ion battery that is charged with Constant Current – Constant Voltage control circuit. The device has two modes for motor direction, the Hold-to-Stop function with an extra Screw Tightening feature, and the constant voltage on the brushed DC motor with overcurrent protection.

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

Contents

1. Terms and Definitions

CC	Constant Current
CV	Constant Voltage
DC	Direct Current
DFF	D Flip-Flop
HV	High voltage
LUT	Look-up Table
OSC	Oscillator

2. References

For related documents and software, please visit:

https://www.renesas.com/eu/en/products/programmable-mixed-signal-asic-ip-products/greenpak-programmable-mixed-signal-products/greenpak-high-voltage-programmable-mixed-signal-matrix

Download our free Go Configure Software Hub [1] to open the .hv file [2] and view the proposed circuit design. Use the 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] GreenPAK Designer Software, Software Download and User Guide, Renesas Electronics

[2] AN-CM-364 Rechargeable Electric Screwdriver.hv, Design File, Renesas Electronics

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

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

[5] SLG47105 Datasheet, Renesas Electronics

[6] AN-CM-363 CCCV Battery Charger, Application note, Renesas Electronics

3. Introduction

The main goal of this application is to design a Rechargeable Electric Screwdriver using the SLG47105V. The system is designed using the HV macrocells and other internal and external components to drive a 3 V DC-DC Motor as well as charging the battery.

The proposed device is a rechargeable screwdriver, powered by a 3.7 V Li-ion battery. The battery can be charged by any USB power adapter using implemented Constant Current – Constant Voltage charging method.

The device has two modes for motor direction, the Hold-to-Stop function with an extra Screw Tightening feature, and the constant voltage on the brushed DC motor with overcurrent protection.

Only one SLG47105 allows us to create a complete device with charging control, motor driving, overcurrent protection, and other interface features.

Figure 1: Rechargeable Electric Screwdriver

4. Operating Principle

The block diagram of the Rechargeable Electric Screwdriver is shown in Figure 2.

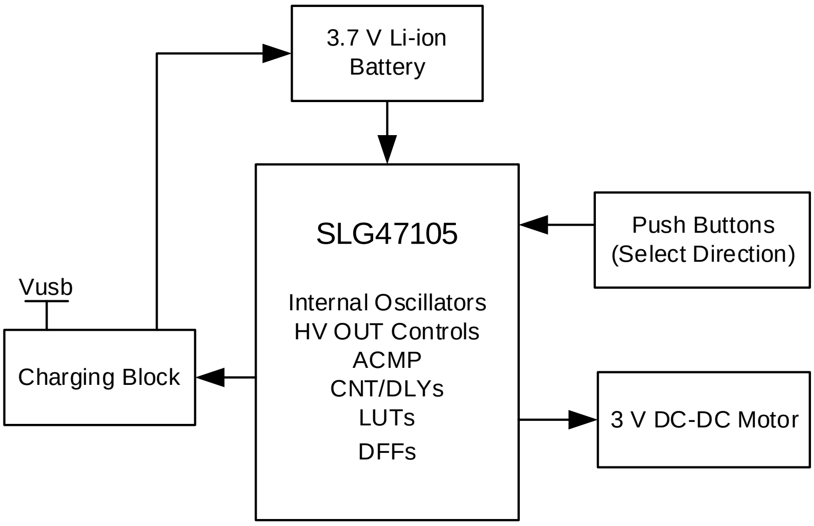

Figure 2: Block Diagram

The 3 V DC-DC Motor with 200 rpm was selected to create a screwdriver. There are two push buttons to select the motor direction clockwise and counterclockwise for screwing and unscrewing, respectively.

The device is powered with a 3.7 V Li-ion Battery. When the USB charger is connected, the SLG47105 detects the voltage level and starts the appropriate stage of CC-CV charging begins.

The full circuit schematic is presented in Figure 3.

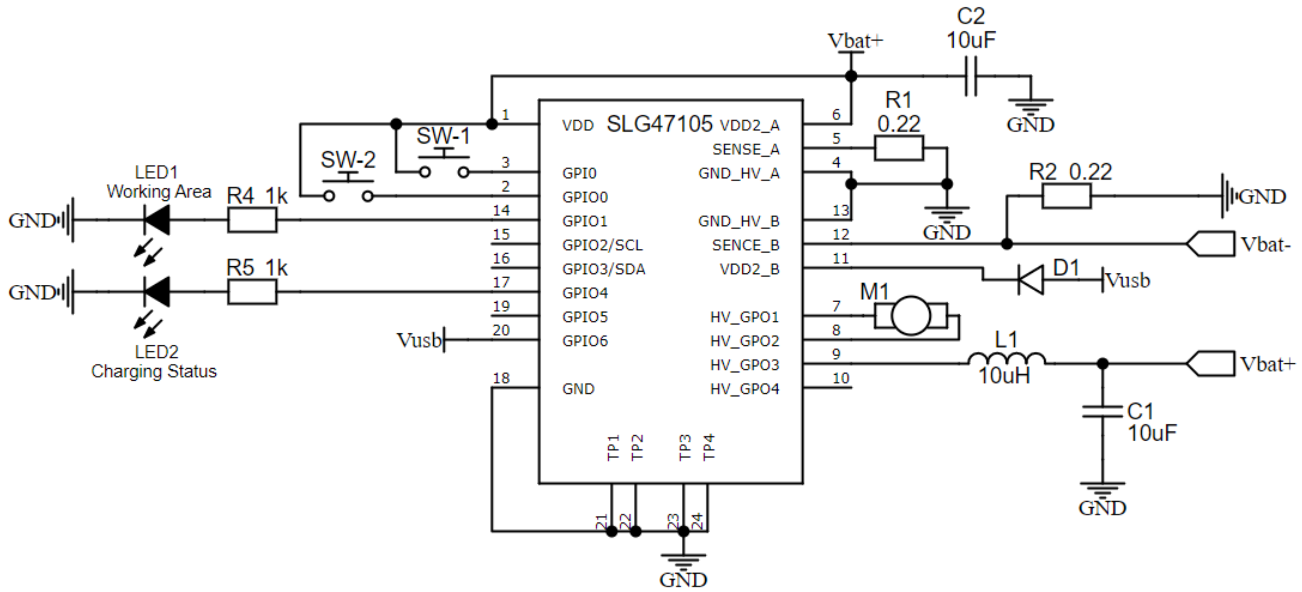

Figure 3: Full Circuit Schematic

There are also two LEDs to notify about the process. The LED1 (white) indicates the screwdriver working – the motor is ON. The LED2 (red) indicates the charging process: constant ON – charging, blinking - charging is complete.

5. GreenPAK Design

The GreenPAK Design consists of two parts Screwdriver Motor and USB Charging. The Screwdriver Motor part is shown in Figure 4.

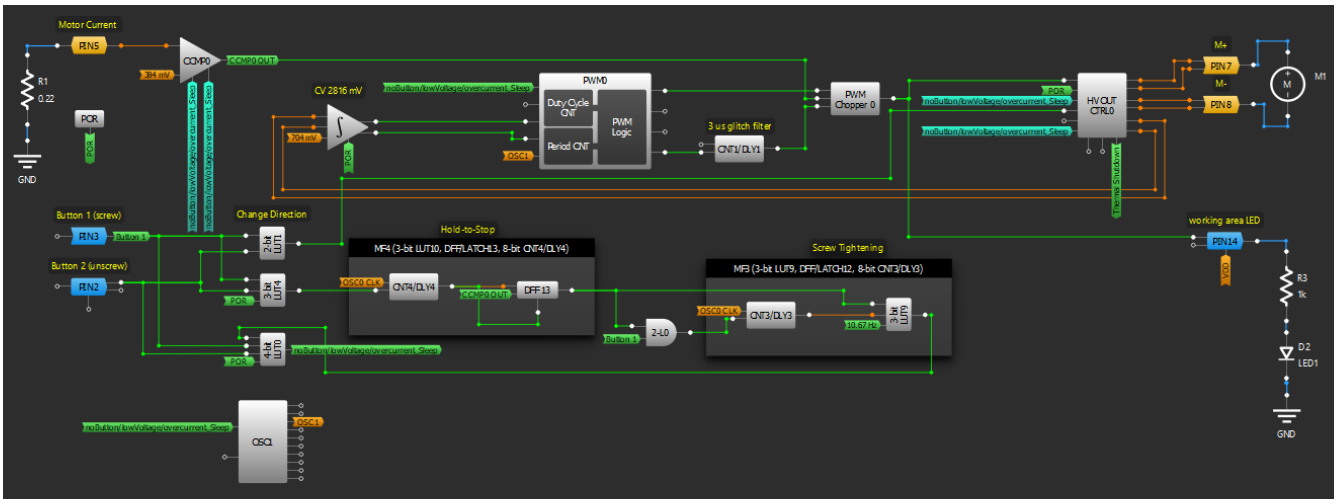

Figure 4: Screwdriver Motor GreenPAK Design

The PWM0 block provides a ~50 kHz signal with a PWM depending on the load voltage at the motor. The Diff+ and Diff- of the HV OUT CTRL0 are connected to HV_GPO0_HD and HV_GPO1_HD of the Differential Amplifier with Integrator and Analog Comparator. This macrocell is useful when there is a need to keep the constant voltage at the Full Bridge load. The integrated DC voltage level is applied to the comparator`s negative input. The Differential Amplifier with Integrator and Analog Comparator outputs are used to control the PWM duty cycle. In this case, a closed loop system controls the PWM duty cycle to ensure the constant average output voltage level. Then the PWM0 signal goes to the PWM Chopper 0 macrocell. The CCMP0 checks the motor current, this signal goes to the Chop input of the PWM Chopper 0 macrocell. If it is higher than the maximum allowable current, the HIGH signal on the CCMP0 cuts the PWM0 signal decreasing the duty cycle. As a result, we have the same PWM0 signal but with a lower duty cycle to avoid overcurrent. The CNT1/DLY1 sets the 3 us Blanking Time of the PWM Chopper 0.

To select a direction of the motor there are PIN2 for unscrewing and PIN3 for screwing that are connected to push buttons. 2-bit LUT1, 3-bit LUT4, and 4-bit LUT0 are used for selecting purposes and to power down the device if no button is pushed or two buttons are occasionally pushed at the same time. In addition, the MF4 macrocell is used for the Hold-to-Stop function with an extra Screw Tightening feature (screw mode) on MF3. This feature triggers five ~10 Hz pulse signals to the motor during 500 ms to tighten the screw and then powers down the system.

The system works only when VDD is higher than 3 V (ACMP1).

The USB Charger part is presented in Figure 5. To get more information please see [6].

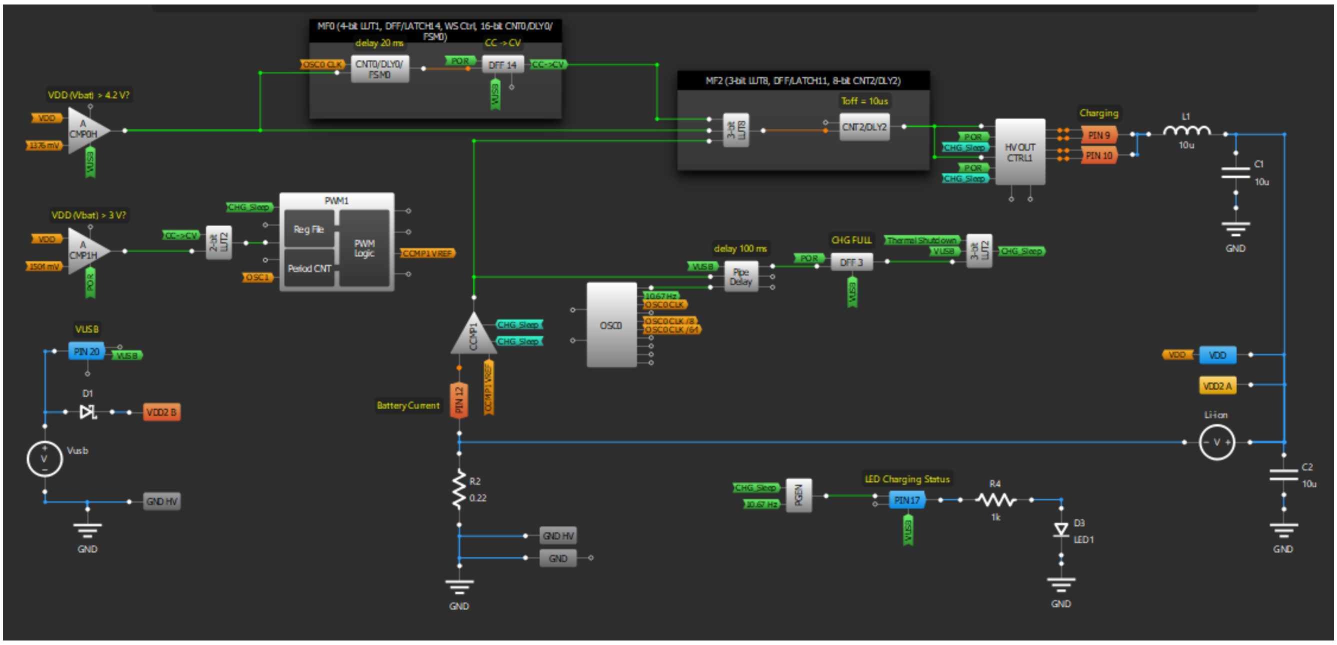

Figure 5: USB Charger GreenPAK Design

If the Vusb is connected, ACMP0 and ACMP1 check the VDD (Vbat) voltage. If this voltage is lower than 3 V the **Pre-charge** starts. In this case, the Up/Down input of the PWM1 macrocell is LOW, which means that we start charging from 160 mV for CCMP1 Vref (Figure 6). As a result, the CCMP1 maintains the ~ 90 mA current.

Reg File Data:

Byte #	Value	Duty Cycle	Vref
0	29	11.37 %	960 mV
1	4	1.57 %	160 mV
2	4	1.57 %	160 mV
3	4	1.57 %	160 mV
4	4	1.57 %	160 mV
5	4	1.57 %	160 mV
6	4	1.57 %	160 mV
7	4	1.57 %	160 mV

Figure 6: CCMP1 Vref Reg File Data

As soon as the ACMP1 output is HIGH (the Vbat is higher than 3 V), the **Constant Current** phase starts. In this case, the Up/Down input of the PWM1 is HIGH, so the CCMP1 Vref is 960 mV. The resulting current is ~ 550 mA. Note that these current limits can be changed by changing the Vref value in the Reg File or by changing the resistor R2 connected to the PIN 12 (Sense B).

This CC phase continues until the battery voltage reaches 4.2 V (ACMP0 output is HIGH). Then the CC stops and the **Constant Voltage** phase starts. In this case, the ACMP0 controls the constant voltage of 4.2 V and the CCMP1 just checks and keeps the current decreasing and lower than 90 mA until the battery is fully charged. When the battery is fully charged, the charging process stops and all corresponding blocks are in Sleep Mode -> CHG_Sleep is HIGH.

6. Device Testing

The following Figure 7, Figure 8, Figure 9 show the signal on the motor terminal depending on VDD (Vbat).

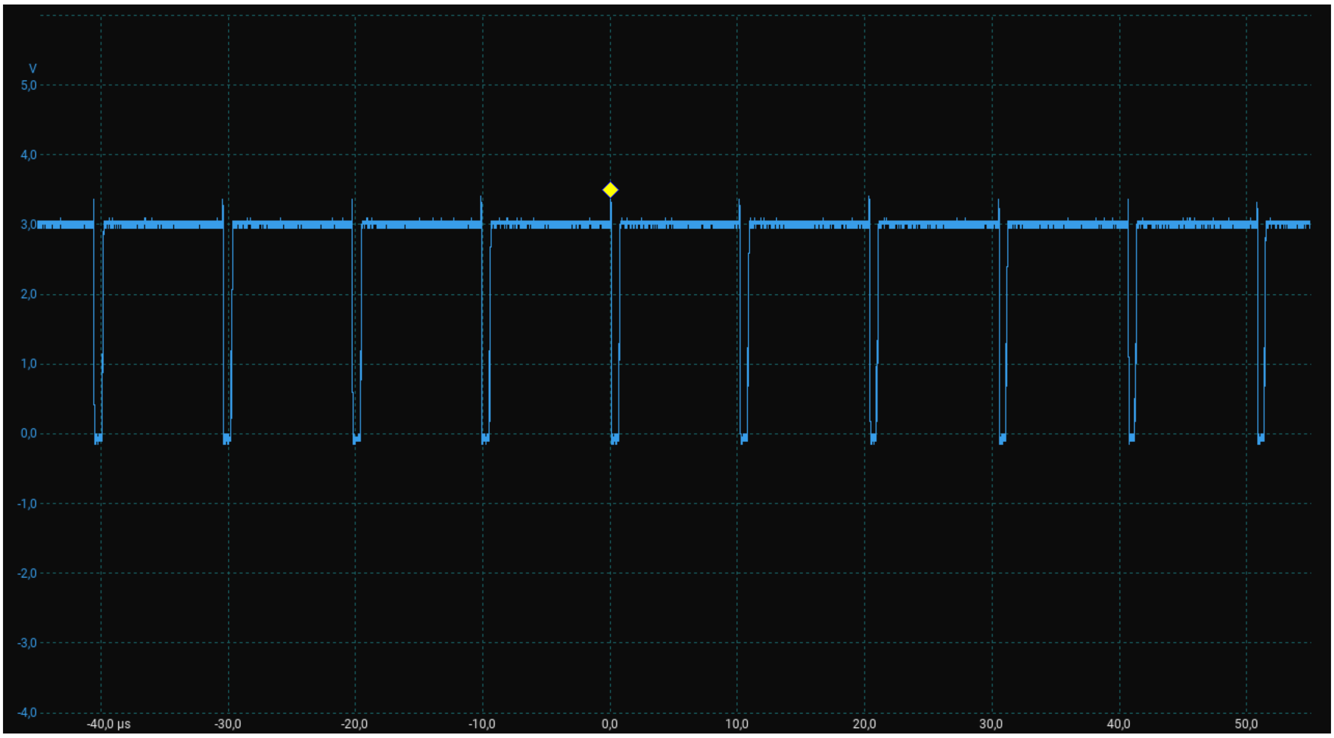

Figure 7: VDD = 3 V, duty cycle 94%

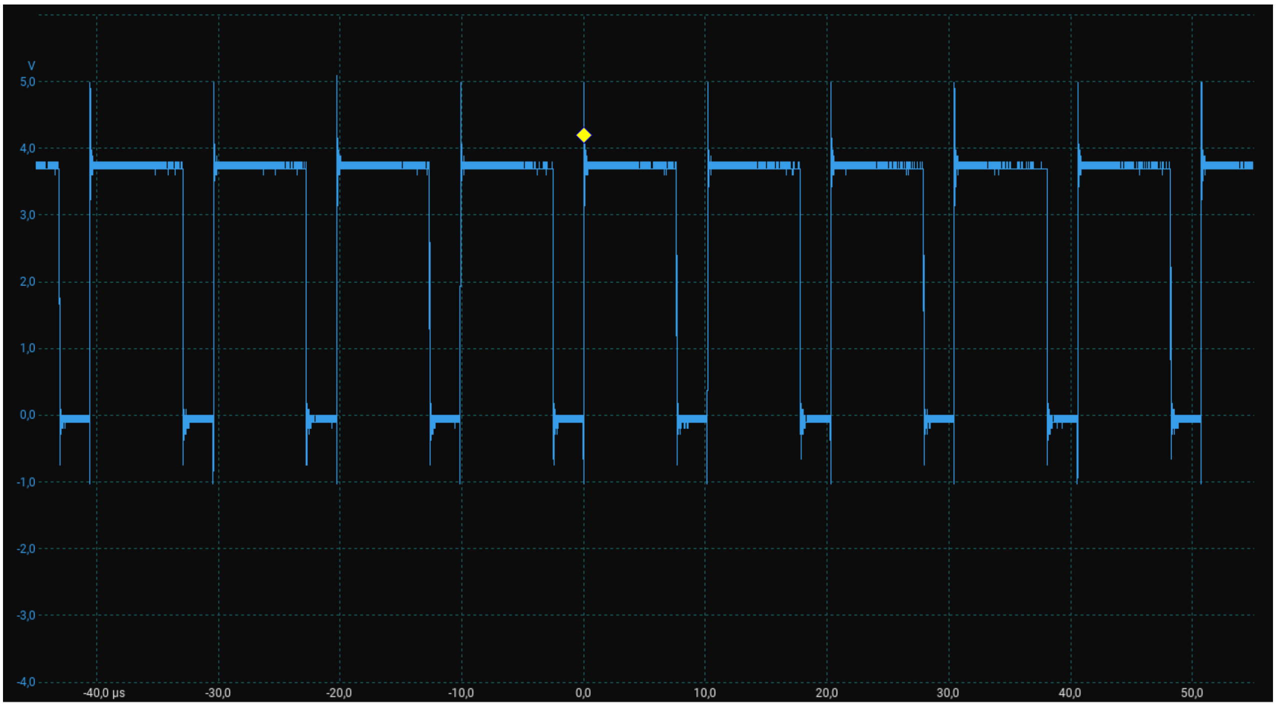

Figure 8: VDD = 3.7 V, duty cycle 75%

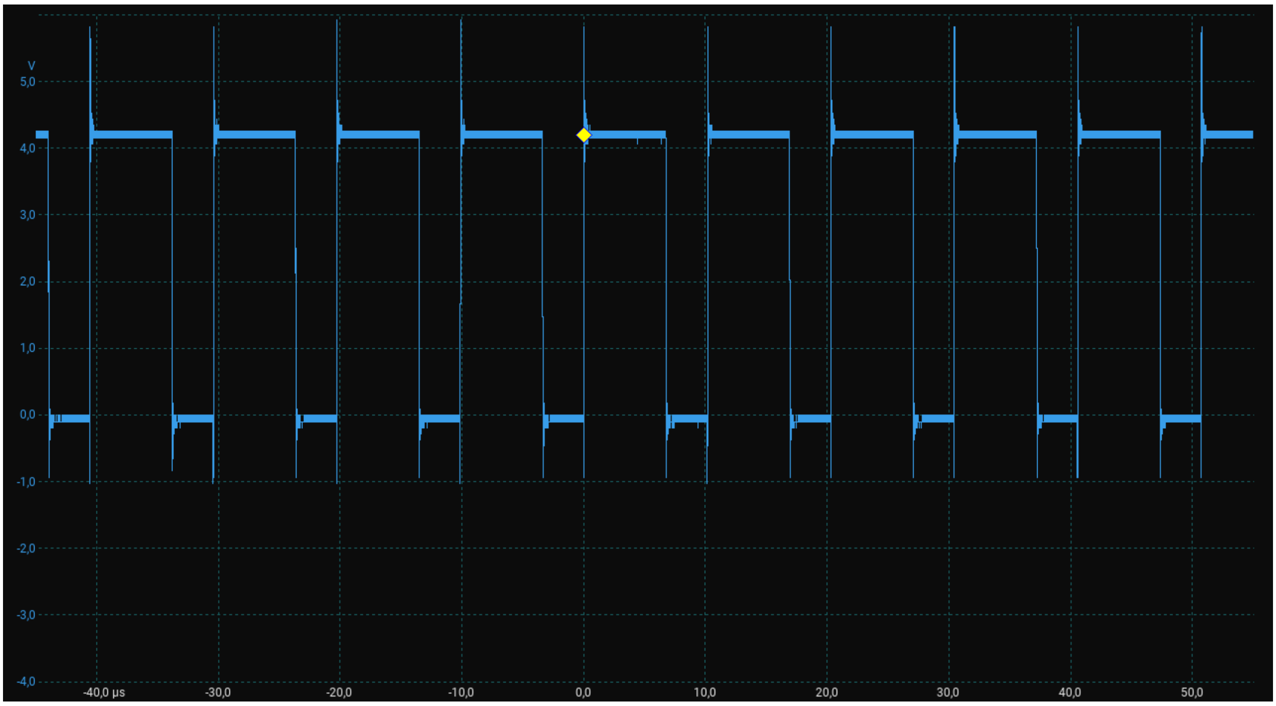

Figure 9: VDD = 4.2 V, duty cycle 67%

7. Conclusion

This application note describes how to configure the HVPAK to create a Rechargeable Electric Screwdriver. The results prove that the circuit works as expected, and the SLG47105 is capable of acting as the control module for the 3 V DC-DC Motor and 3.7 V Li-ion Battery charger at the same time.

In addition, the device has two modes for motor direction, the Hold-to-Stop function with an extra Screw Tightening feature, and the constant voltage on the motor.

The GreenPAK's internal resources, including the HV, oscillators, logic, and GPIOs are easy to configure to implement the desired functionality for this design.

8. Revision History

Revision	Date	Description
1.00	Apr 24, 2023	Initial release.

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