

Rechargeable Toy Car with Push-to-Start/Hold-to-Stop Functionality

SLG47105

This application note describes how to create a Rechargeable Toy Car with Push-to-Start/Hold-to-Stop Functionality 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 also provides 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.

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1. Terms and Definitions

CC	Constant Current
CV	Constant Voltage
DC	Direct Current
DFF	D Flip-Flop
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 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 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-365 Rechargeable Toy Car with Push-to-Start/Hold-to-Stop Functionality.hvp](#), 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] SLG47105 Datasheet, Renesas Electronics

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

[7] Video <https://www.renesas.com/video/rechargeable-toy-car-push-starthold-stop-functionality>

3. Introduction

The Magic Track Toy Car has small size and provides fast and efficient movement on the track, allowing children to enjoy high-speed races and exciting adventures (Figure 1).

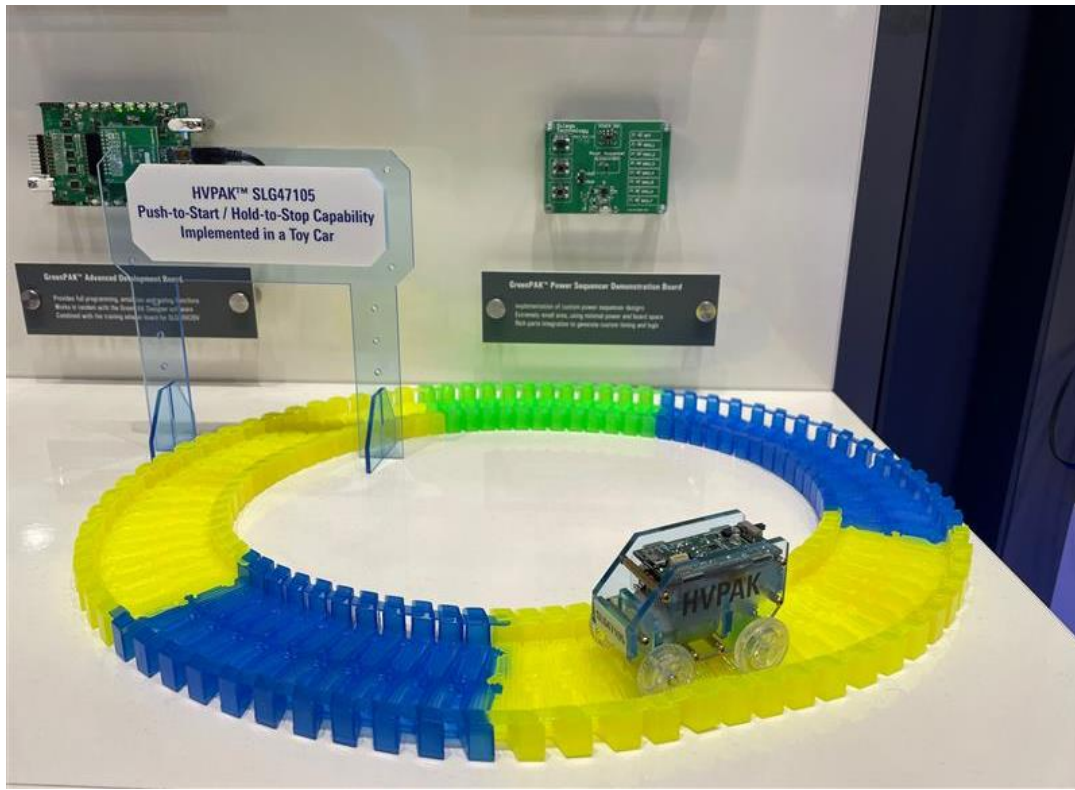


Figure 1: Magic Track Toy Car

This application note describes how to create the Rechargeable Toy Car with Push-to-Start/Hold-to-Stop using HVPAK SLG47105. The following design provides constant voltage on the motor, regardless of the battery charge and "Push-to-Start / Hold-to-Stop" capability. Thanks to the Hold-to-Stop functionality, the car automatically turns off when it's stuck. So, if the child directs it somewhere and forgets about the toy, the car will switch off and will not consume more power, thus saving the battery. The CC-CV battery charger control is also implemented.

Only one SLG47105 and a few extra components allow to create a complete device with charging control, motor driving, overcurrent protection, and other interface features.

4. Operating Principle

The full circuit schematic is presented in Figure 2.

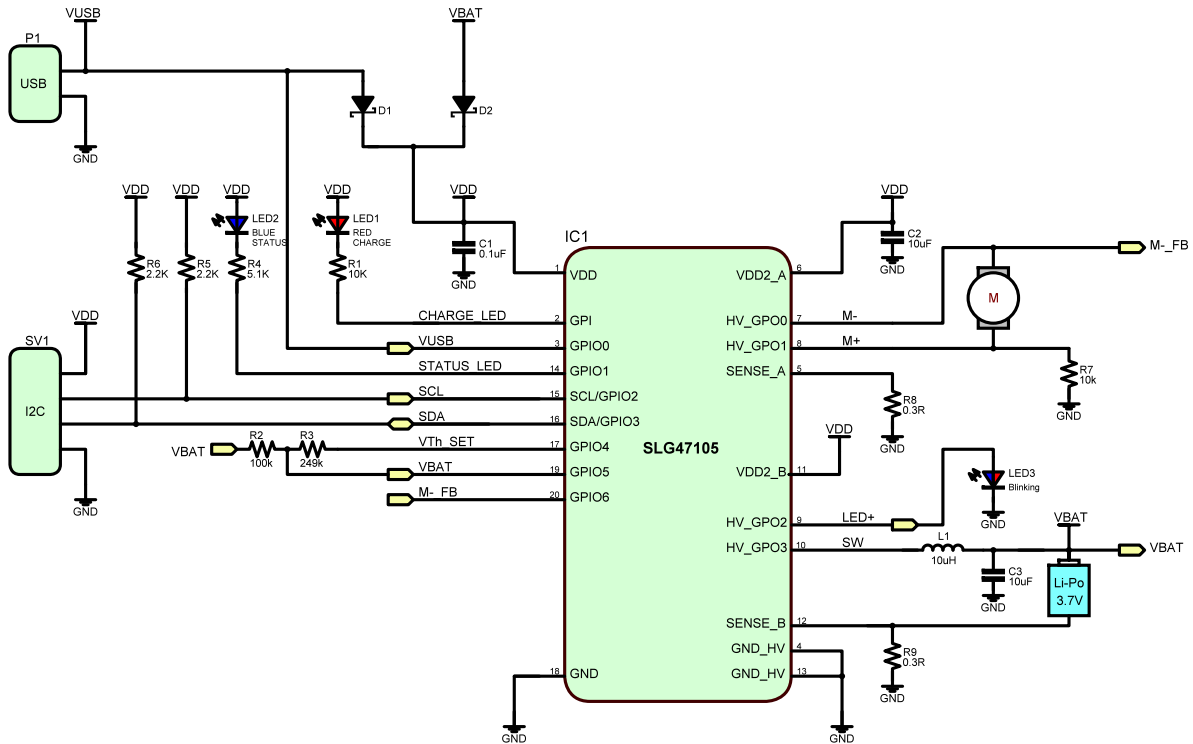


Figure 2: Full Circuit Schematic

The Brushed DC Motor is used for this project. If the car is pushed, SLG47105 detects it and the car starts driving. If it is held, the system powers down. 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 the appropriate stage of CC-CV charging begins. The motor is blocked during charging.

There are also three LEDs to notify about the process.

- LED1 (RED) is CHARGE. Blinking represents the charging process. The LED is ON when the charge is complete. The LED is OFF when no USB is connected.
- LED2 (BLUE) is STATUS. If $V_{BAT} < 3\text{ V}$ – blinking. If $V_{BAT} > 3\text{ V}$ – the LED is ON if the car drives and the LED is OFF when the car doesn't move.
- LED3 (BLUE&RED) blinking means car movement.

The proposed PCB design is shown in [Figure 3](#).

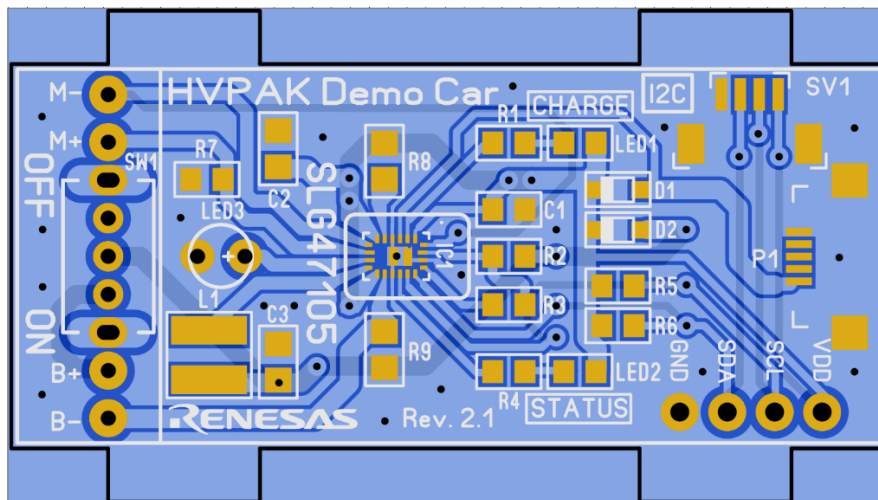


Figure 3: HVPAK Demo Car PCB

5. GreenPAK Design

The GreenPAK Design consists of two parts Motor Control and USB Charging. The Motor Control part is shown in [Figure 4](#).

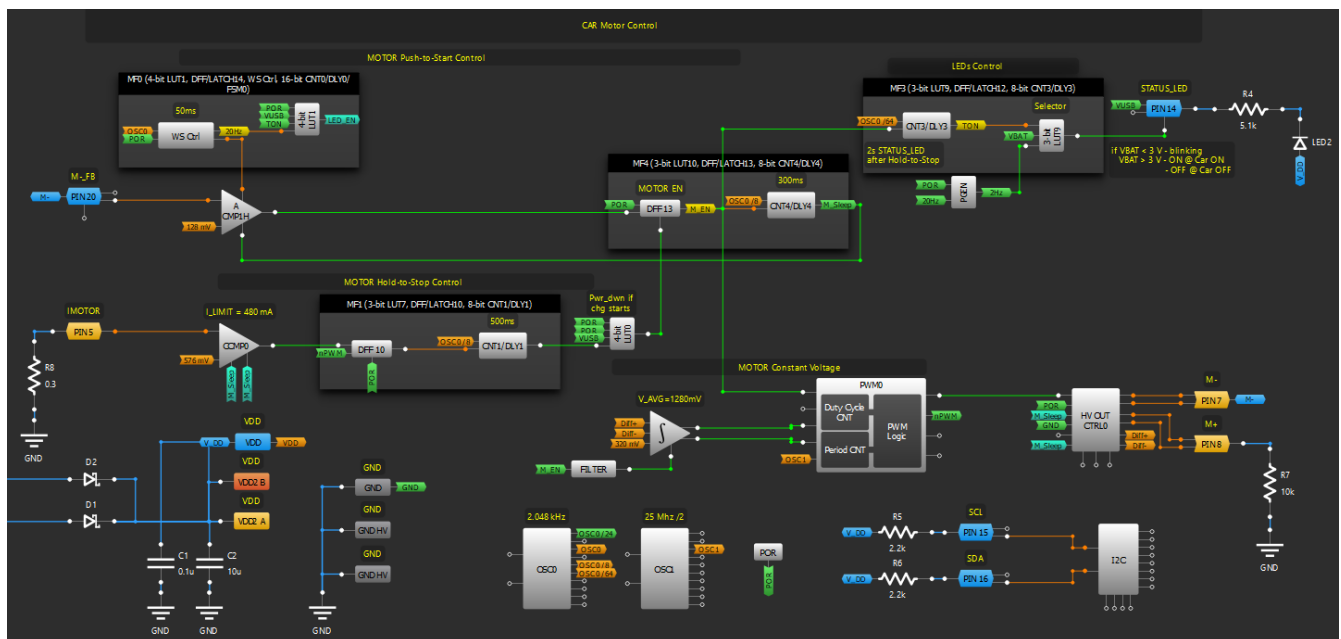


Figure 4: Car Motor GreenPAK Design

The PWM0 block provides a ~50 kHz signal with a PWM depending on the load voltage at the motor. The HV_GPO0_HD and HV_GPO1_HD of the Differential Amplifier with Integrator and Comparator are connected to Diff+ and Diff- of HV OUT CTRL0 (first Full Bridge). 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 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.

The ACMP1H is connected to the M- motor terminal and checks if the car was pushed. When the shaft of the DC Motor rotates in the coil according to the electromagnetic induction law, an electromotive force (EMF) is induced. This signal is detected by ACMP1H. Its output goes to DFF13 which then enables the PWM0 block. 4-bit LUT1 provides an Enable signal for LED3 when the car is ON. To avoid battery discharge ACMP1H is connected to the 50 ms Wake Sleep Controller.

When the shaft of the DC Motor is held to stop, the current increases. The CCMP1 is connected to the Sense A resistor (PIN5) and monitors the current. Its output goes to MF1 which detects exceeding the limit of this current. If it lasts longer than 500 ms (CNT1/DLY1), the HIGH signal from 4-bit LUT0 resets the DFF13 and the system is powered down. The HV OUT CTRL0 is powered down with a 300 ms delay to give the motor some time to stop and avoid restarting the system. Also, the VUSB detect signal is connected to 4-bit LUT0, so if it is HIGH (the USB is connected) the system is powered down as well.

MF3 and PGEN provide controlling and selecting functions for LED1 and LED2 described in [4 Operating Principle](#).

The USB Charger part is presented in [Figure 5](#). To get more information please see [\[6\] above](#).

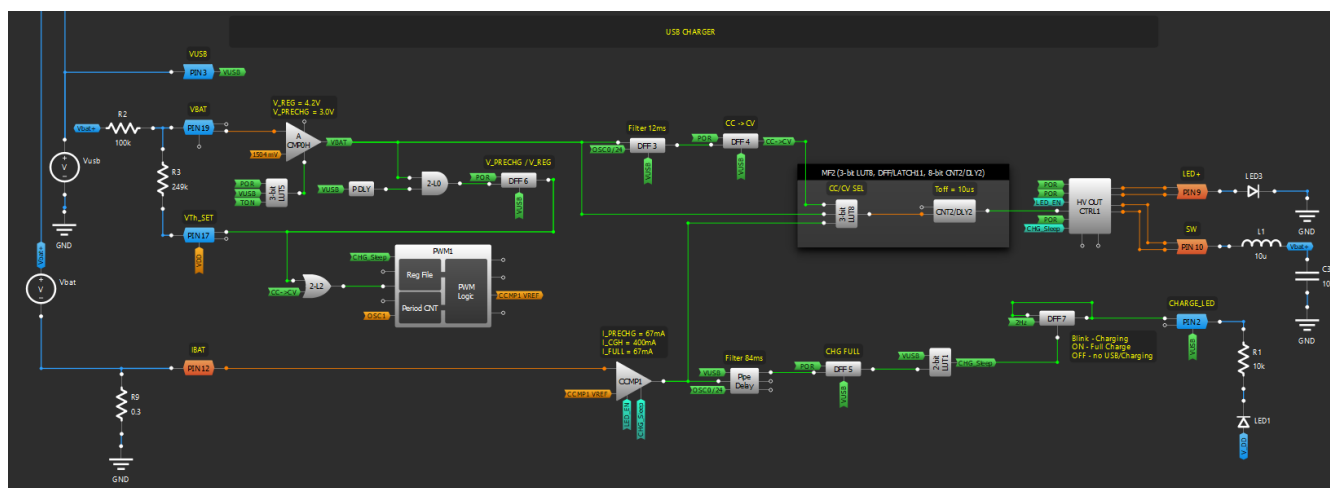


Figure 5: USB Charger GreenPAK Design

If the Vusb is connected, PIN3 detects it and powers ON the ACMP0H. The ACMP0H checks the Vbat voltage. DFF6's output is HIGH, so no voltage divider is connected to PIN19 (IN+ Source with x8 gain of the ACMP0H). If Vbat is lower than 3 V the **Pre-charging** stage starts. PWM1 sets the current and CCMP1 controls it. In this case, the Up/Down input of the PWM1 macrocell is LOW, which means that we start charging from Vref = 160 mV for CCMP1 Vref (Figure 6). As a result, the CCMP1 maintains the 67 mA current:

$$I_{bat} = \frac{V_{ref}}{\text{Gain} \cdot R_{sense}}$$

As soon as the ACMP0H output is HIGH (the Vbat is higher than 3.0 V), the DFF6 output goes to LOW and the voltage divider is connected to PIN19. The **Constant Current** phase starts. In this case, the ACMP0H makes a comparison for 4.2 V (not 3.0 V as in 1st case). The Up/Down input of the PWM1 is HIGH, so the CCMP1 Vref is 960 mV. The resulting current is ~ 400 mA. Note that these current limits can be changed by changing the Vref value in the Reg File or by changing the resistor connected to the PIN 12 (Sense B).

This CC phase continues until the battery voltage reaches 4.2 V (ACMP0H output is HIGH). Then the Constant Current stops and the **Constant Voltage** phase starts. The Up/Down input of the PWM1 is LOW, so the CCMP1 Vref is 160 mV. In this case, the ACMP0H controls the constant voltage of 4.2 V, and the CCMP1 just checks and keeps the current decreasing and lower than the I_{BF} of 67 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).

Reg File Data: [\[1\]](#)

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

6. Device Testing

Please, see also the [video](#) of the working Rechargeable Toy Car with Push-to-Start/Hold-to-Stop Functionality.

The following [Figure 7](#), [Figure 8](#), [Figure 9](#) and [Figure 10](#) show the signal on the motor terminal depending on VDD (Vbat).

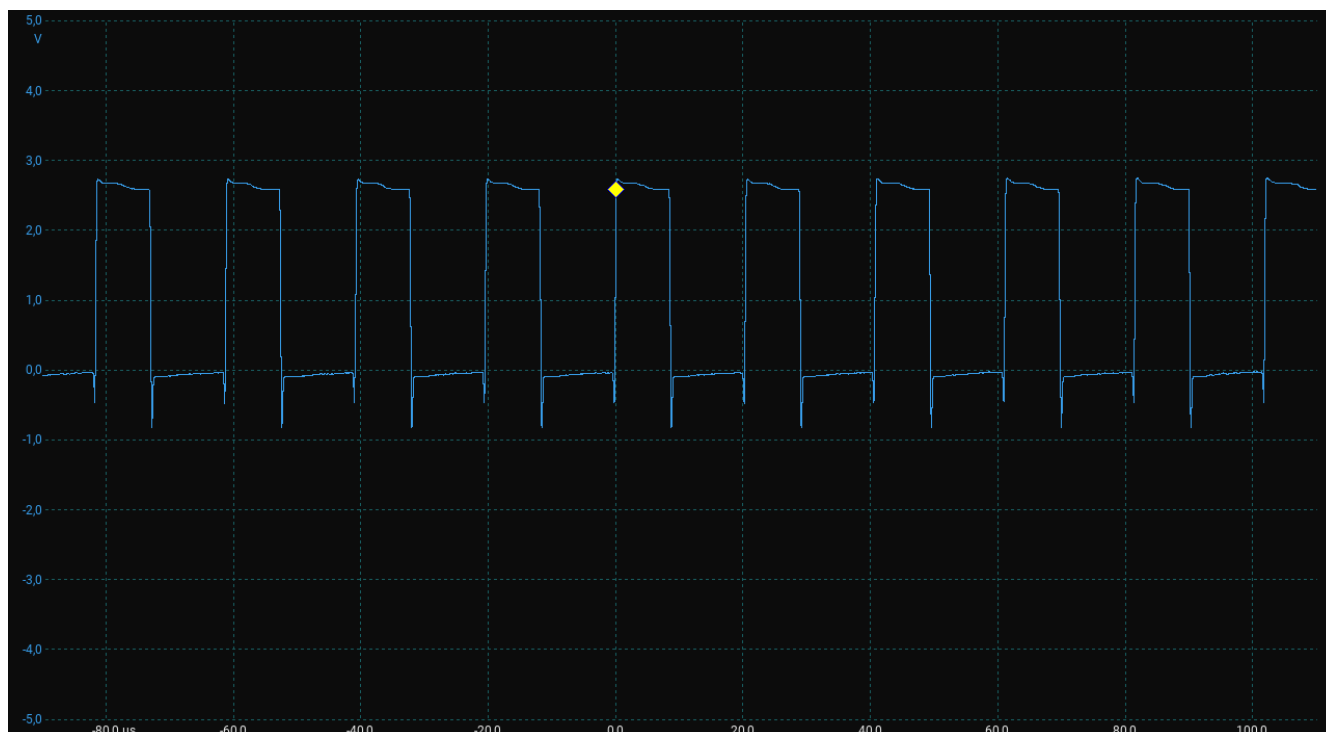


Figure 7: VDD = 3.0 V, duty cycle 43%

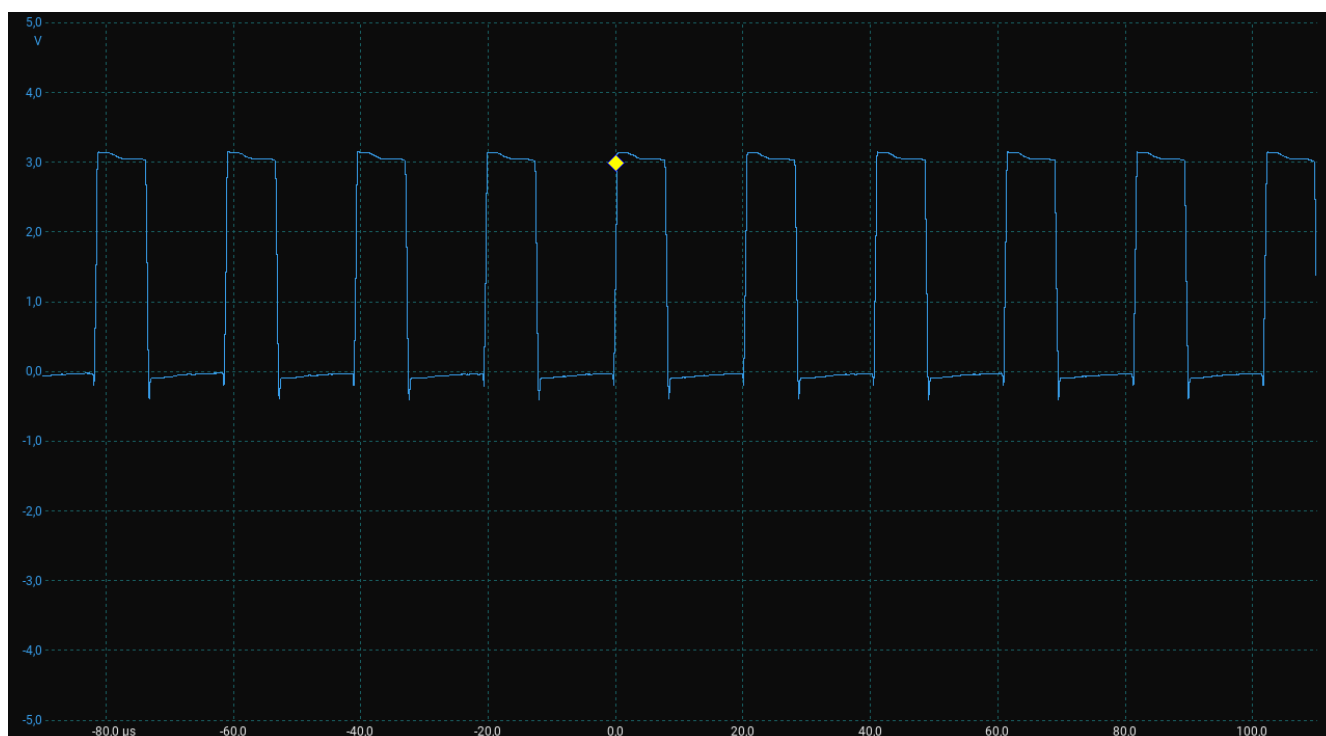


Figure 8: VDD = 3.4 V, duty cycle 40%

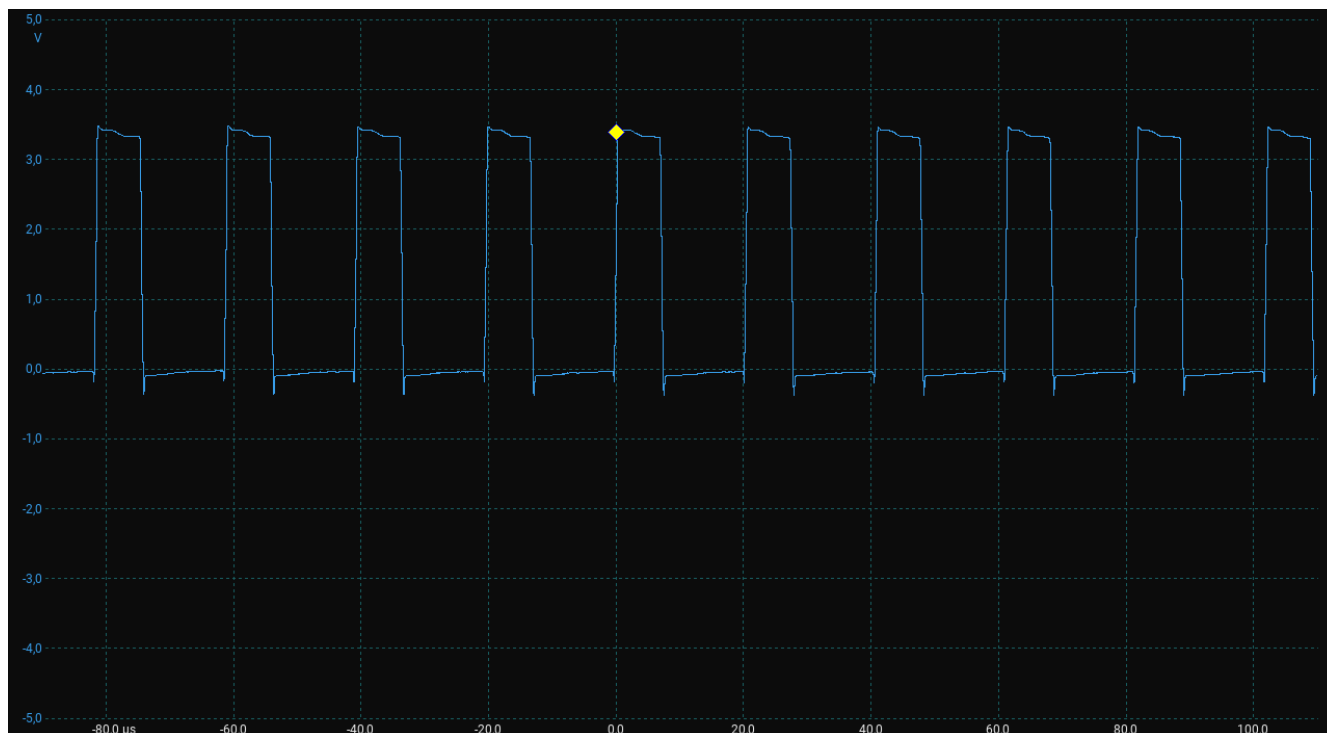


Figure 9: VDD = 3.7 V, duty cycle 35%

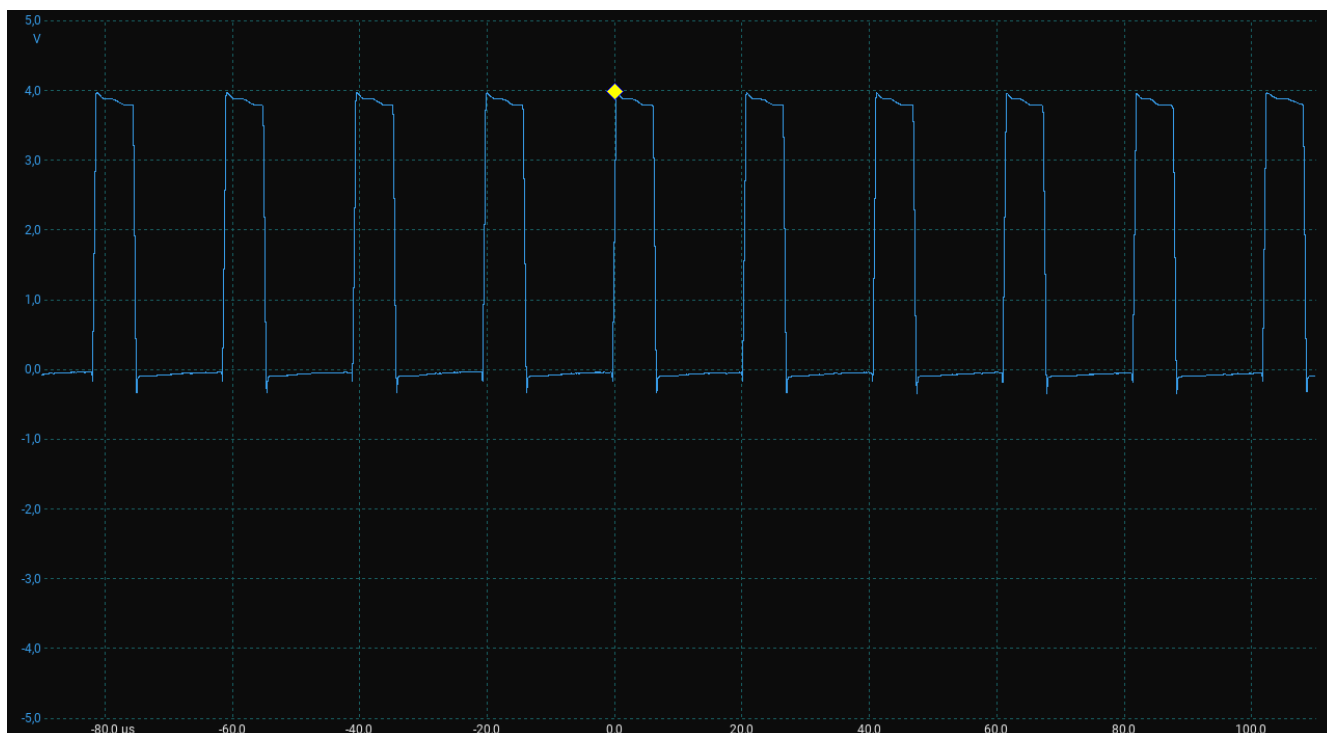


Figure 10: VDD = 4.2 V, duty cycle 31%

Figure 11 shows the peak on PIN20 (M- terminal) during Push-to Start which power ON the system.

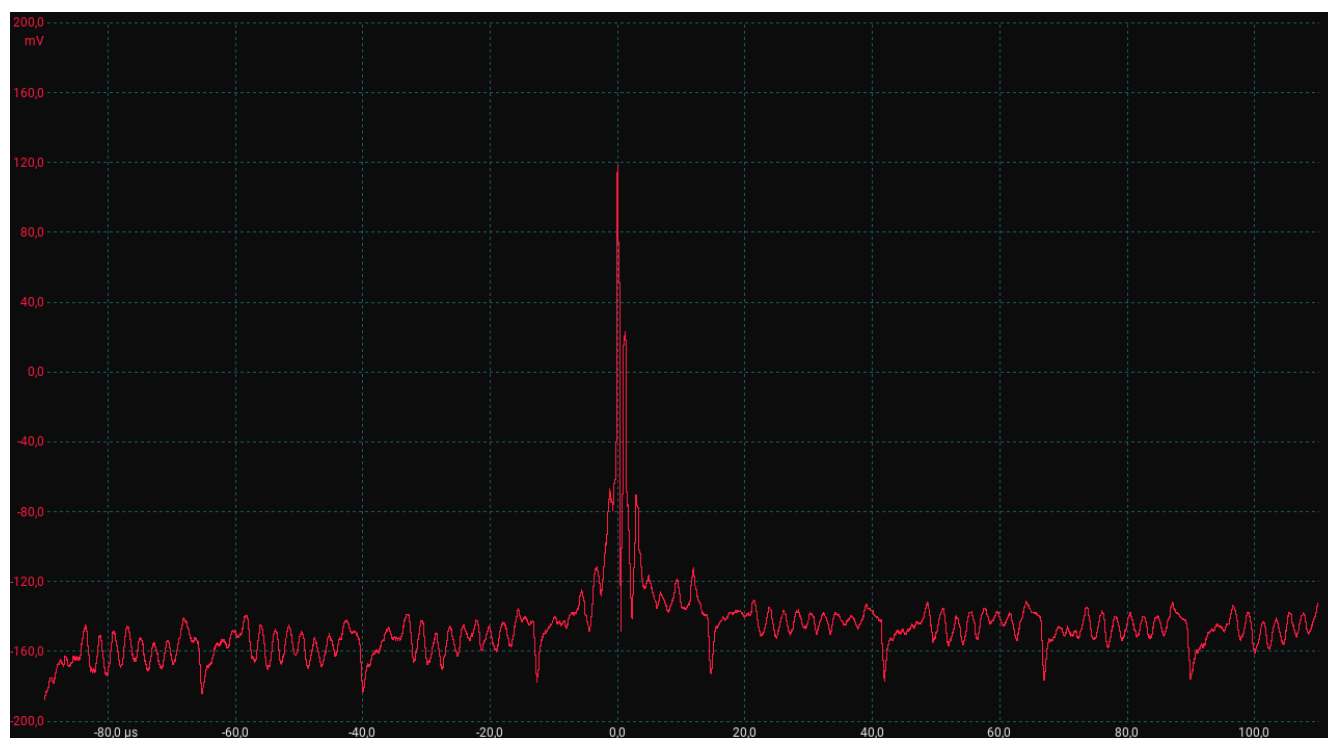


Figure 11: Peak on PIN20 (M- terminal) during Push-to-Start

7. Conclusion

In this application note a Rechargeable Toy Car with Push-to-Start/Hold-to-Stop Functionality has been build using the HVPAK. The results prove that the circuit works as expected, and the SLG47105 is capable of acting as the control module for the Brushed DC Motor and 3.7 V Li-ion Battery charger at the same time.

The HVPAK'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	May 4, 2023	Initial release.

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