

# Remote TX and RX Control System for Toy Applications

## SLG47513 and SLG47105

This application note describes how to design and build a pair of encoder/decoder dedicated to working with cheap RF modules.

The encoder is based on the low voltage IC SLG47513 which can be powered from a single 1.5 V battery. It also has a charge pump that doubles the voltage to power the RF transmitter module.

The decoder is built on the SLG47105. The IC is equipped with two high current bridge outputs which eliminate the need for external transistors allowing the direct motor connection.

Both ICs contain a large amount of general purpose and specialized macrocells allowing designing the remote control system with almost no external components excluding RF modules.

The application note comes complete with a design file that can be found in the [Reference](#) section.

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## 1. Terms and Definitions

CNT/DLY	Counter-Delay
GPO	General Purpose Output
IC	Integrated Circuit
I/O	Input / Output
I2C	Inter-Integrated Circuit Protocol
LED	Light Emitting Diode
MUX	Multiplexer
OSC	Oscillator
PCB	Printed Circuit Board
RF	Radio Frequency
RX	Receive Dada
TX	Transmit Data
SCL	Signal Clock
SDA	Signal Data

## 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/hvpak>

Download our free Go Configure software Ref. [1] and use the GreenPAK development tools Ref. [2] to freeze the design into your own customized IC in a matter of minutes.

Renesas Electronics provides a complete library of application notes Ref. [3] featuring design examples Ref. [1] as well as explanations of features and blocks within the Dialog IC.

- [1] [Go Configure Software](#), Download, and User Guide, Renesas Electronics
- [2] [GreenPAK Development Tools](#), GreenPAK Development Tools Webpage, Renesas Electronics
- [3] [GreenPAK Application Notes](#), GreenPAK Application Notes Webpage, Renesas Electronics
- [4] [SLG47513 Datasheet](#), Renesas Electronics
- [5] [SLG47105 Datasheet](#), Renesas Electronics

<https://www.renesas.com/document/cm-344-gp-file>

## 3. Introduction

The circuits described in this document are designed to replace commonly used TX-2B/RX-2B ICs in low-budget RF-controlled toys. The main advantages of the proposed design are:

for TX

- Ability to work with any digital RF transmitter on the 433.92 MHz (315 MHz or any other allowed in your area) frequency
- Low power supply voltage (0.9 V to 1.65 V). Single AAA battery for example
- Extremely low current consumption when idle eliminating the need for a power switch
- No trimming or any kind of adjusting

for RX

- Ability to work with any digital RF receiver on the 433.92 MHz (315 MHz or any other allowed in your area) frequency
- No external transistors or any motor drivers
- Wide power supply range. 2.3 V to 5.5 V for core and 3 V to 13.2 V for high current outputs
- RX and low battery indicator
- Undervoltage battery protection
- No trimming or any kind of adjusting

As a downside, it should be mentioned that this design offers four functions instead of five, but in most cases «Forward», «Backward», «Turn Right», and «Turn Left» are the only required functions. Making the design perfect for a majority of RF-controlled toys.

See the schematic diagram of the TX-2B/RX-2B in [Figure 1](#) and the schematic diagram of the proposed design using SLG47513 and SLG47105 ICs in [Figure 2](#).

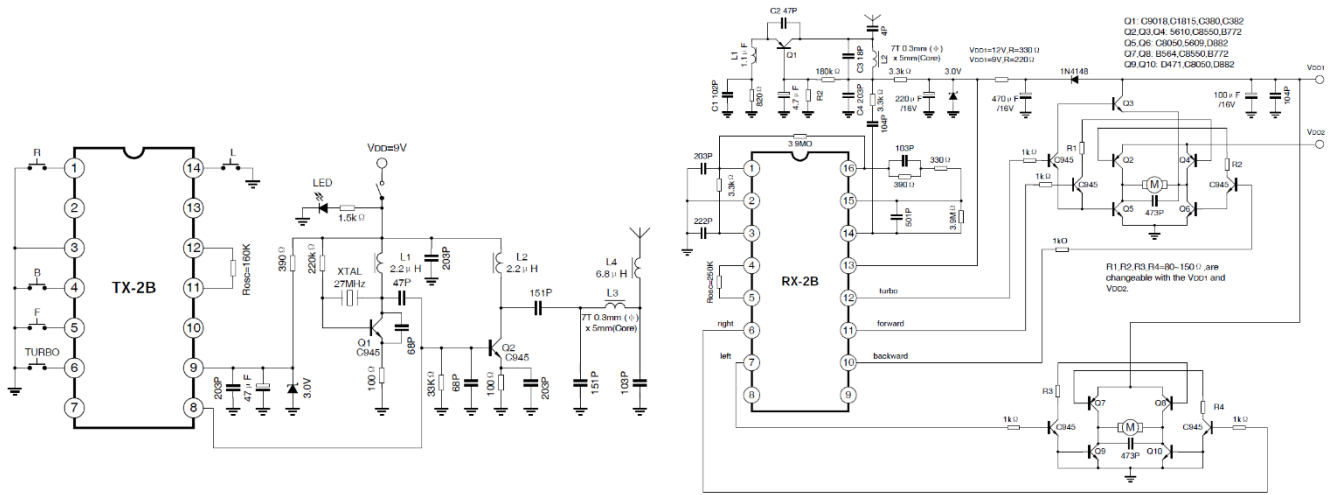


Figure 1: TX-2B/RX-2B Recommended Circuit

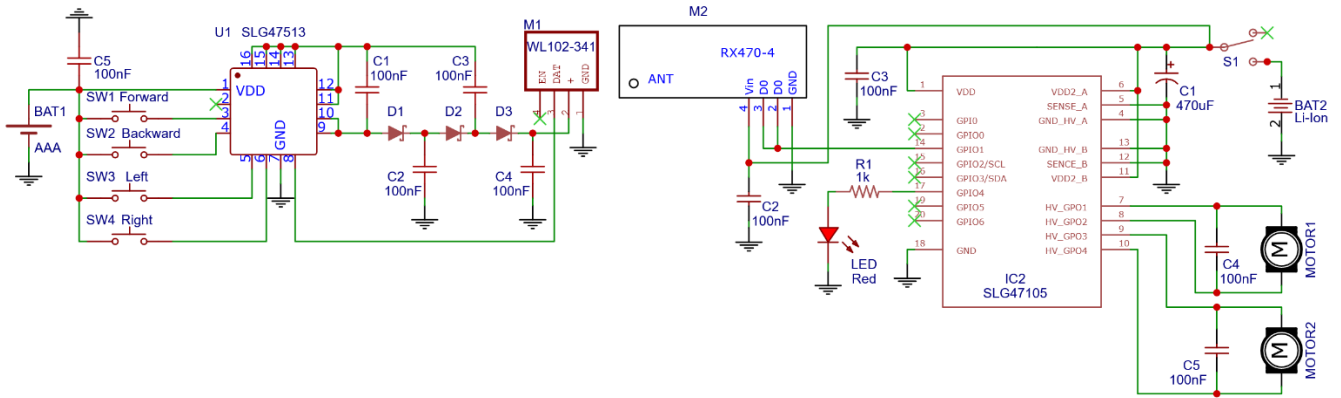


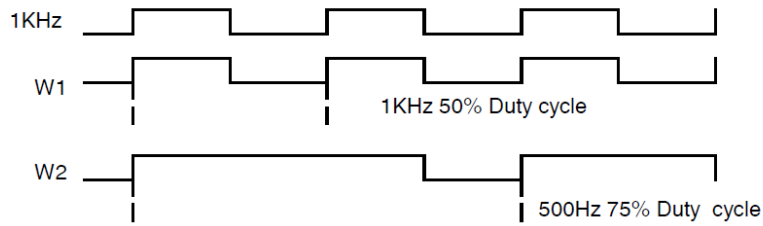
Figure 2: Remote Control System Using SLG47513 and SLG47105

## 4. Theory of Operation

### 4.1 Code Format

Encode rule for this design is exactly the same as TX-2B/RX-2B uses, see [Figure 3](#). [Table 1](#) shows functions for each of the four codes. Note that the function codes are different but if needed can be configured as in the TX-2B for direct functional replacement. In this case, RX design using the SLG47513 can be considered as a standalone project with the benefit of using only one 1.5 V battery.

(A).Bit Format (W1 is used for function codes,W2 for start codes)



(B).Date Format

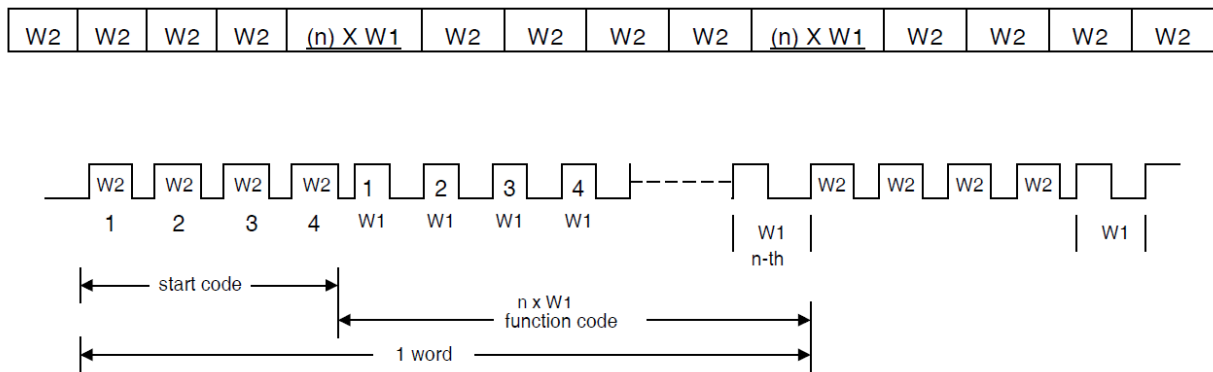


Figure 3: TX Code Format

Table 1: Code Function

Code (n) W1	Function Button	Decode Result
28	Left	Turn Left
34	Right	Turn Right
46	Backward	Go Backward
52	Forward	Go Forward

It should be mentioned that this particular design is made for a toy car with fixed front wheels which has two motors each driving both front and rear wheels on each side. So the car turns when motors are reversed and goes forward or backward when motors rotate in the same direction (like any vehicle with tracks), see [Figure 4](#). Also, this design is suitable for toy boats with two propellers, see [Figure 5](#).

However, with almost no effort this design can be changed to suit more traditional toy cars where one motor drives rear wheels and the other motor is used to turn front wheels.

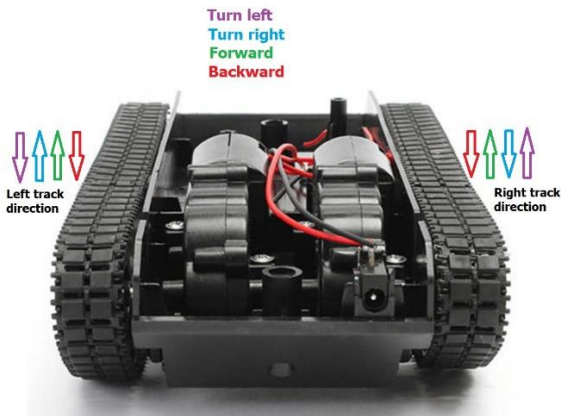


Figure 4: Tank Moving Principle

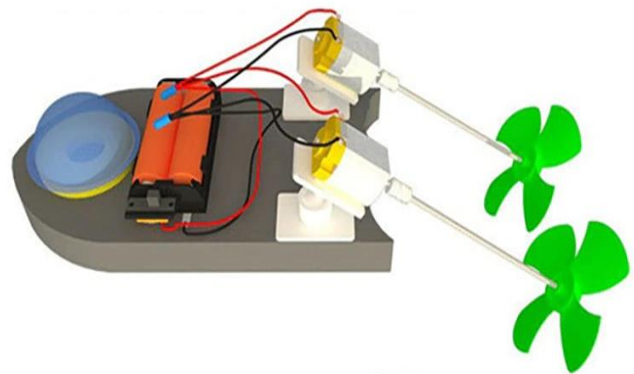


Figure 5: Toy Boat with Two Propellers

## 4.2 TX Encoder

The SLG47513 IC turned out to be perfect for creating an encoder for RF-controlled devices. It contains all necessary macrocells to create the design using a minimum of external components. See [Figure 6](#) for the Go Configure screenshot of the project. The circuit does not require a power switch due to extremely low power consumption when idle, less than 1  $\mu\text{A}$ . Until any of the buttons are pressed, all oscillators and other macrocells remain in static mode and thus do not consume any current. To start the operation user should press the button of the desired function. The 4-bit LUT0 (OR) detects any button pressed and enables OSC0 (through an inverter) and OSC1. All of the MF macrocells along with the OSC0, PGEN, and 3-bit LUT4 (multiplexer) are used to form pulse sequences resembling one of four codes for each function. MF0 and PGEN form the start code W2 and MFs 1 to 4 form function codes W1. The MUX switches between W2 and W1 making the code sequence, see [Figure 3](#) and [Figure 7](#) for the time diagrams.

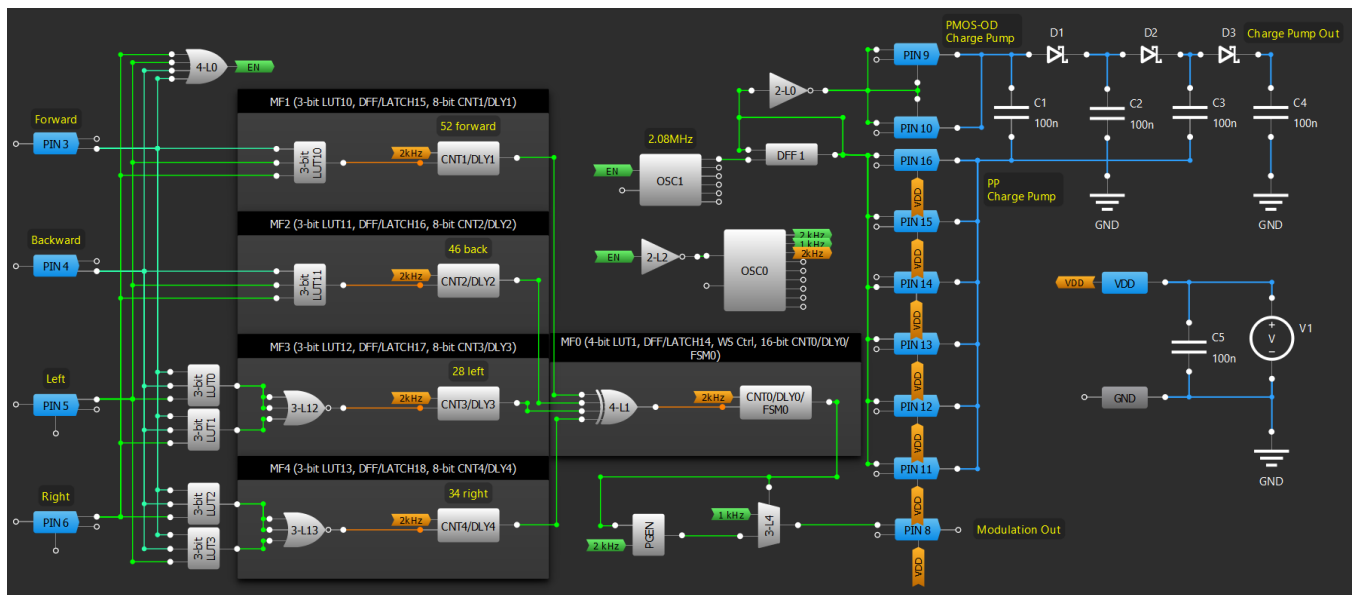


Figure 6: Encoder Using SLG47513. Go Configure Project

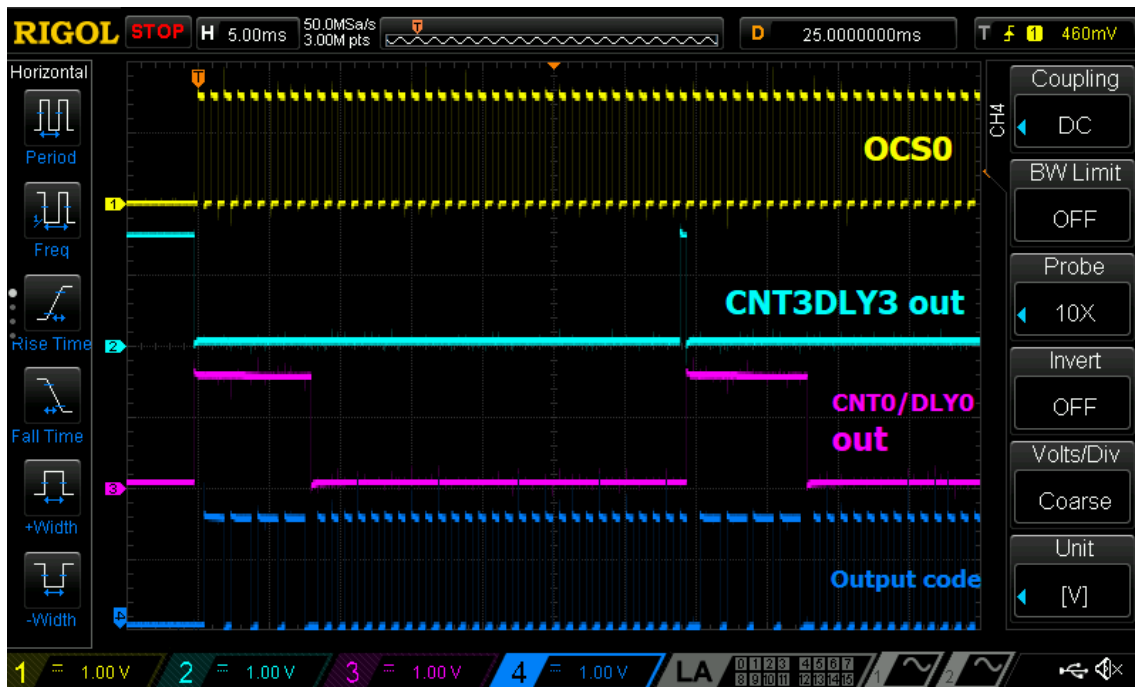


Figure 7: Oscilloscope Screenshot. Function Button «Left», Code 28

Also, the design includes a charge pump for powering the transmitter module. It is built using OSC1 (25 MHz / 12), DFF1, and an inverter (2-bit LUT0). Pins 9 and 10 are configured as a 2x drive, 3-state output. When the OE input is High the pin acts as a 2x push-pull, and when OE is Low the pin goes into High-Z (3-rd) state. Since IN and OE are connected together, the pin will act as P-MOS open drain output. This configuration allows eliminating one Schottky diode typically used to charge the first capacitor of the charge pump (C1 in this case, see Figure 6). Pin 9 and Pin10 are connected for higher current output. Pins 11 to 16 are also connected together for handling high loads. This charge pump allows doubling (taking into account the diode's voltage drop) the power supply voltage to meet the minimum power requirements of the RF module.

### 4.3 RX Decoder

The decoder and motor driver are built using the SLG47105 chip. It contains all necessary macrocells including all of the configurable logic, high voltage high current full bridge outputs to drive two DC motors, and even ACMP which is used to detect low battery < 3V preventing it from damaging, assuming Li-ion or Li-pol batteries are used. See Figure 8 for the Go Configure Project screenshot.

The OSC0 is configured to an external clock from Pin14 where the RF receiver output is connected. This allows passing the received signal to the CNT0/DLY0 which detects the start code and triggers four CNT/DLYs which decode received function codes. The input signal goes directly from the Pin14 to the clock inputs of all of the CNT/DLYs (0 to 4) bypassing the internal clock circuit.

The CNT0/DLY0 output is connected through a small delay (P DLY) to the Reset In of each of the code detecting CNT/DLYs (1 to 4). So, until the start code is detected by CNT0/DLY0 all other four CNT/DLYs will be constantly reset. But when the start code is detected, CNT0/DLY0's output goes Low allowing detection of the function code. For each code detecting, CNT/DLYs Counter data = Function code – 1. That is 27 for «Turn Left», 33 for «Turn Right», 45 for «Backward», and 51 for «Forward». If the detected function code is > 27 the CNT1/DLY1 will trigger DFF10 to a High level on its output. Then it will be reset by the start code which alternates with the function code and the decoding procedure will start all over. If the detected function code is > 33 both the CNT1/DLY1 and CNT2/DLY2 will trigger their DFFs to a High level on their outputs. Code > 45 will be detected by CNT1/DLY1, CNT2/DLY2, and CNT3/DLY3. And code > 51 will be detected by all four CNT/DLYs. See Figure 9 for an example of code 28 detection and Figures 10 to 13 for output signals on the outputs of the DFF10 to DFF13 (yellow, sky blue, purple, and blue respectively) for each code.

# Remote TX and RX Control System for Toy Applications

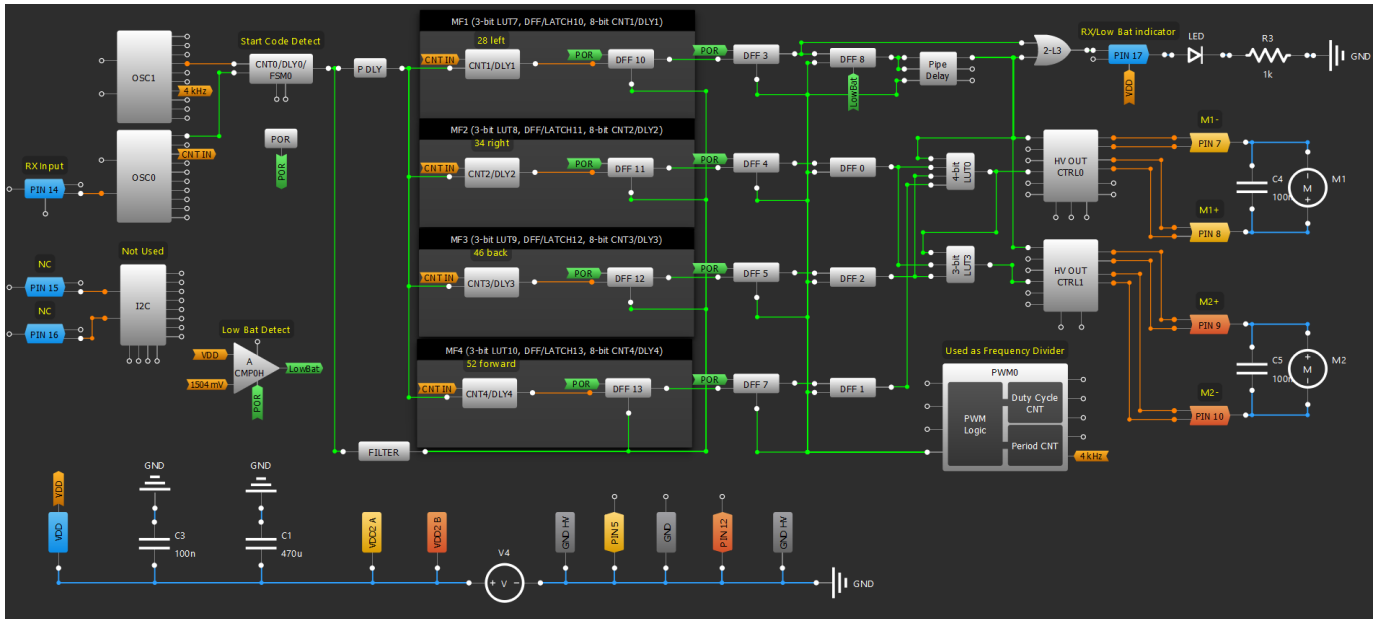


Figure 8: Decoder Using SLG47105. Go Configure Project

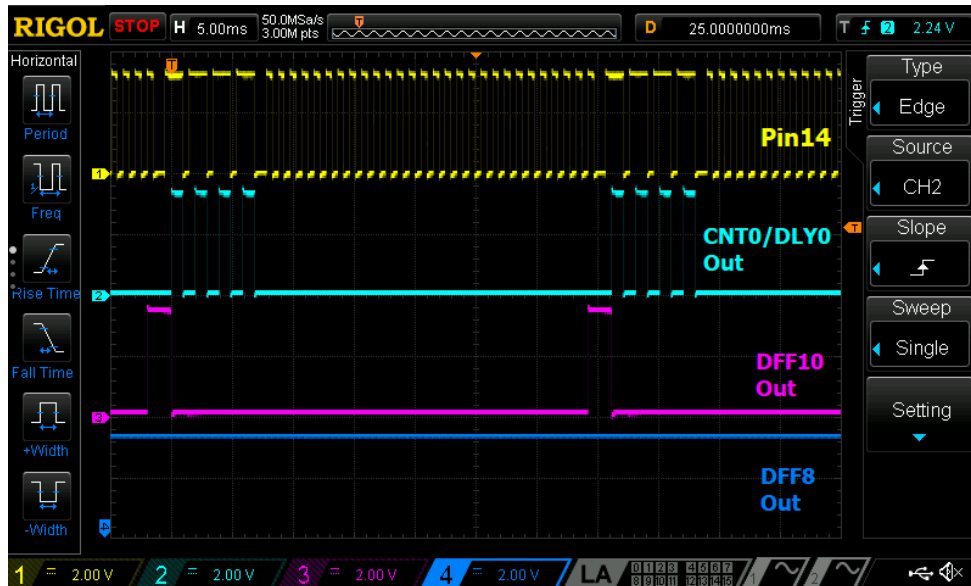


Figure 9: Example of Code 28 Detection

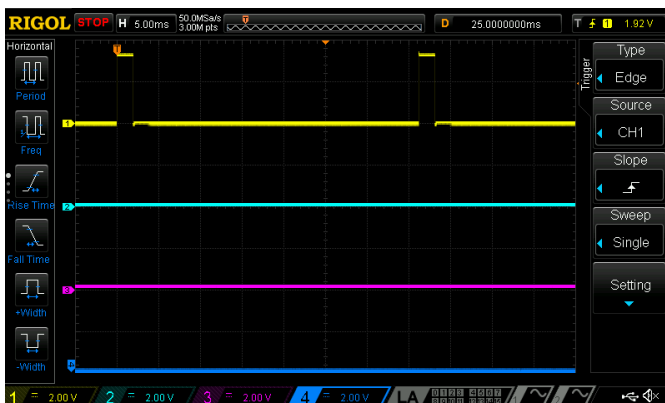


Figure 10: DFF10 to DFF13 Outputs. Code 28

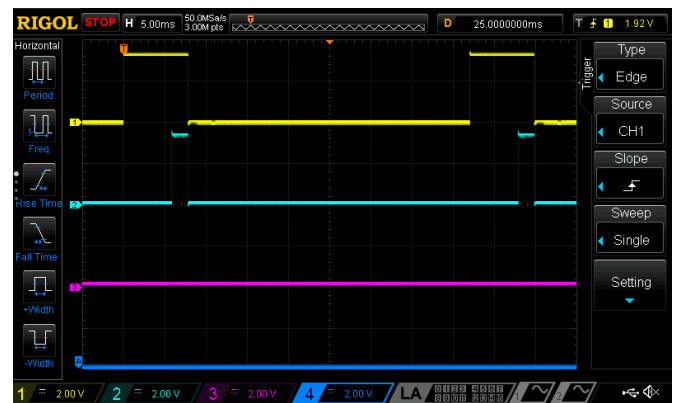


Figure 11: DFF10 to DFF13 Outputs. Code 34



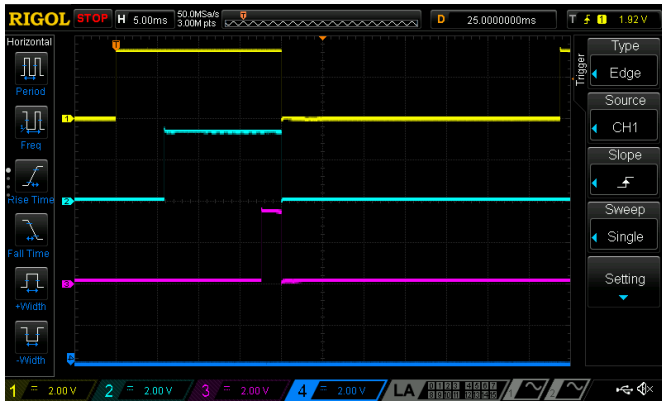


Figure 12: DFF10 to DFF13 Outputs. Code 46

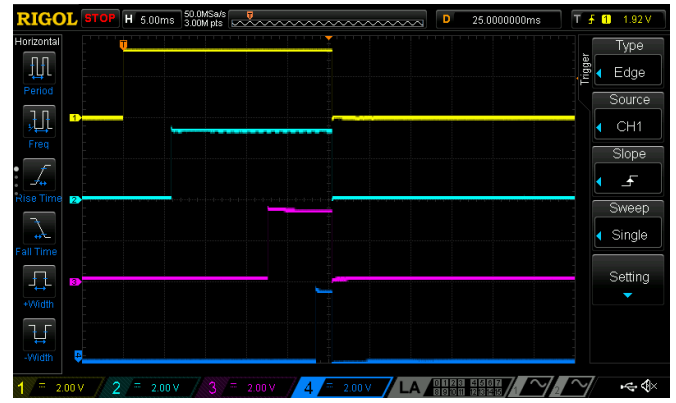


Figure 13: DFF10 to DFF13 Outputs. Code 52

Since the output signal of each DFF (DFF10 to DFF13) is reset by the start code, additional DFFs are used to hold the signal for 62.5 ms. DFFs 3 and 8 for code 28, DFFs 4 and 0 for code 34, DFFs 5 and 2 for code 46, DFFs 7 and 1 for code 52. If during that time the received code hasn't changed, the output remains High. For this purpose, the PWM0 macrocell is used as a frequency divider. It generates short pulses with a frequency of 16 Hz which reset mentioned earlier DFFs every 62.5 ms.

Additional logic is used to convert signals from DFFs 0 to 2 and 8 for the motor driver outputs. 4-bit LUT0 and 3-bit LUT3 serve that purpose. Also, a Pipe Delay was added to synchronize all code outputs (DFFs 0 to 2 and 8) and enable HV outputs simultaneously.

Pin17 is used as an indicator of code detection. If any button on the remote control is pressed, the pin will go High lighting up an LED. It can be used as a toy's headlights. Also, the ACMP0H is configured to detect VDD voltage lower than 3 V. When it does, its output becomes Low and resets DFF8, thus disabling HV outputs. But the decoder is still decoding input signals which go through the 2-bit LUT3 (OR) to the Pin17 resulting in LED blinking indicating the battery is low.

It should be noted that the I<sup>2</sup>C macrocell along with its Pins 15 and 16 are used only to program the chip during production and should not be used during device operation.

The design can be modified so the HV part (VDDA and VDDB) is powered from two or even three Li-ion batteries connected in series (up to 12 V total) and the GreenPAK's core (VDD) along with the RF receiver from one cell. The core current consumption (VDD pin) is insignificantly low and will not cause battery cells to discharge. In this case, higher-power motors can be used for large size toys.

Also since the decoder part is designed to be powered from a Li-ion battery, a separate charging module should be considered.

### 4.4 RF Modules

As mentioned earlier, this project is designed to work in a bundle with cheap RF modules as shown in Figures 14 to 17.

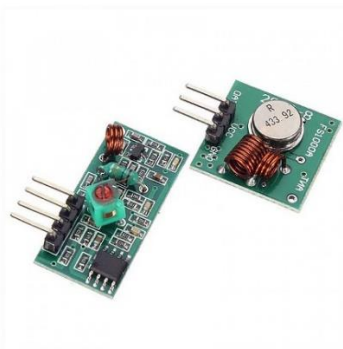


Figure 14: RF module set #1

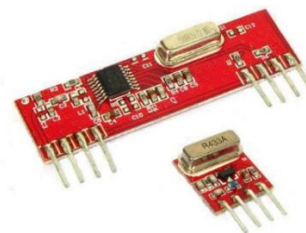
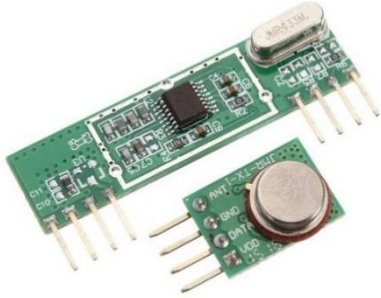
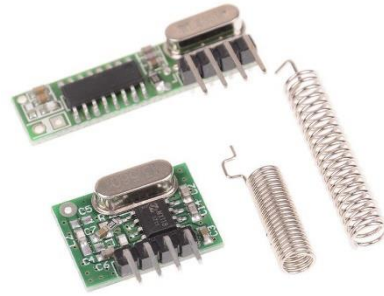


Figure 15: RF module set #2





**Figure 16: RF module set #3**



**Figure 17: RF module set #4**

Any of these modules will work fine, however, the preference should be given to those that have good performance with the lowest voltage power supply. Also, since the transmitter is powered with a voltage close to the minimum allowed, the output RF power is lower than typical. To compensate for that, a good quality antenna should be used. A half-wave piece of wire wound in the spring is good enough as shown in [Figure 17](#), but a commercial set of antennas will do better.

## 5. Conclusions

As can be seen, designing and building a pair of encoder and decoder dedicated to working with cheap RF modules is easy using highly versatile ICs SLG47513 and SLG47105.

Both ICs contain a large amount of general purpose and specialized macrocells allowing designing the remote control system with almost no external components excluding RF modules.

## 6. Revision History

Revision	Date	Description
1.00	Jul 5, 2022	Initial release.

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