

RC Light Controller



Addendum for Addressable LEDs

WS2811, WS2812

Introduction

This document describes an **experimental firmware** for the LANE Boys RC Mk4/Mk4P light controller that can drive Addressable LEDs.

This firmware addresses two use-cases:

- Ability to use LEDs connected to WS2811 ICs at each vehicle light (as used in Traxxas TRX-4M)
- Animated full-color light bars such as “decel light” in drift cars

Limitations

- Due to increased firmware size, only recent light controllers that are using the LPC824 micro-controller can be used
- WS281x devices usually require a stable 5V supply
- Some WS281x devices require a 5V logic signal on the data line, but the light controller only outputs a 3.3V signal. A level-shifter may be required
- There is no polarity protection in WS281x devices; reversing power by accident instantly destroys the WS281x devices
- WS281x devices adjust brightness using pulse width modulation, which can cause flickering in videos
- The firmware supports strings of up to 20 WS281x devices
- The firmware only supports one specific WS281x timing protocol

All these limitation mean that WS281x devices are only suitable for for some use cases and users with a moderate amount of knowledge in electronics.

Connecting WS281x devices

WS281x devices have three inputs: Supply (+) and (-), and a DI (data input).

On the light controller side the WS281x data can be output on **OUT/ISP**, **TH/Tx** and **OUT15S** pin.

OUT/ISP is conveniently accessible on the right side of the Mk4P light controllers, so it is a

good choice.

Connecting WS281x devices to **TH/Tx** is only possible if the Light Controller is using Pre-Processor input, i-Bus or S.Bus – but not when Servo inputs are used.

The WS281x data signal can also output on the switched light output **OUT15S**. A pull-up resistor of about 470 Ohm is required. The switching transistor on **OUT15S** inverts the data signal. To compensate for the inversion the *Configurator* provides an option to transmit an inverted signal to compensate for the transistor.

Using **OUT15S** with a pull-up connected to 5V acts as a “level shifter”, generating a 5V data signal as required by some WS281x devices. In contrast, **OUT/ISP** and **TH/Tx** output a 3.3V data signal, which is not compatible with some WS281x devices.

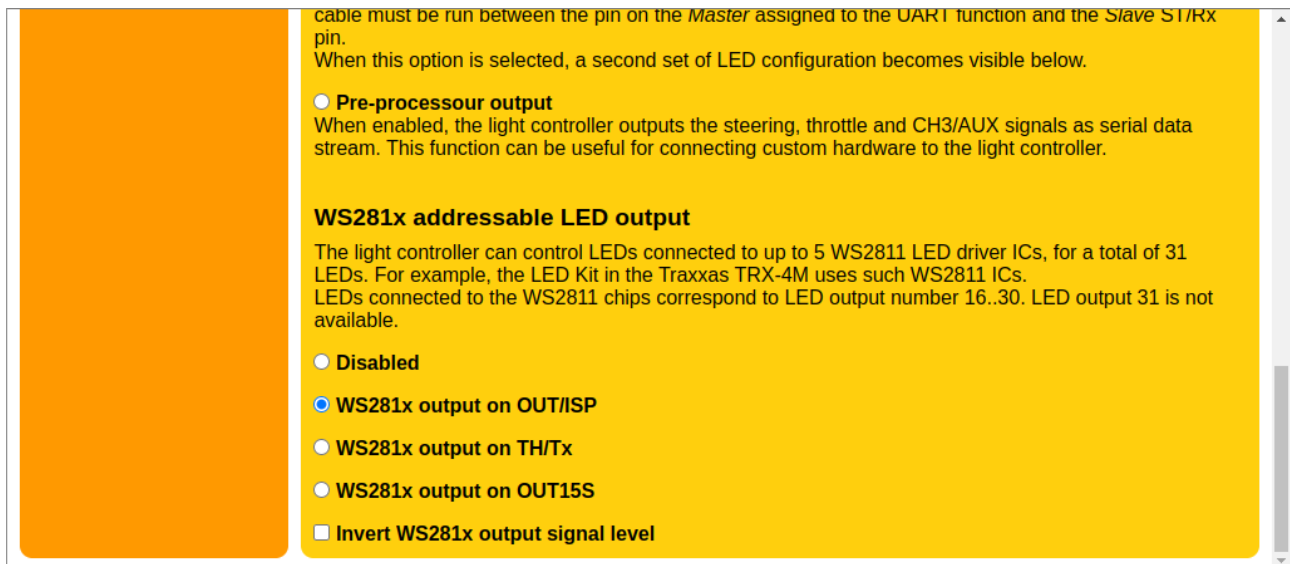
Configuration

The experimental firmware can be accessed through a special version of the *Configurator* at <https://laneboysrc.github.io/rc-light-controller/configurator-ws281x.html>

This firmware is restricted in function, for example it does not support Slave mode or programming Pre-Processors. For those standard functions please use the normal *Configurator* at <https://laneboysrc.github.io/rc-light-controller>

Start by defining the **Operating mode**.

Then enable the WS281x output in the **Output functions** tab.



cable must be run between the pin on the *Master* assigned to the UART function and the *Slave* ST/Rx pin.
When this option is selected, a second set of LED configuration becomes visible below.

☐ **Pre-processor output**
When enabled, the light controller outputs the steering, throttle and CH3/AUX signals as serial data stream. This function can be useful for connecting custom hardware to the light controller.

WS281x addressable LED output
The light controller can control LEDs connected to up to 5 WS2811 LED driver ICs, for a total of 31 LEDs. For example, the LED Kit in the Traxxas TRX-4M uses such WS2811 ICs. LEDs connected to the WS2811 chips correspond to LED output number 16..30. LED output 31 is not available.

☐ Disabled
☒ **WS281x output on OUT/ISP**
☐ WS281x output on TH/Tx
☐ WS281x output on OUT15S

☐ Invert WS281x output signal level

Assign the WS281x to the desired pin on the Light Controller. When using **OUT15S** or an external inverting buffer on the other pins, check the **Invert WS281x output signal level** checkbox.

Single color LEDs connected to WS2811

The WS2811 device is a generic LED driver IC. It has three LED outputs. One could place one IC at each “corner” of the car and drive the corresponding LEDs.

For example, the right front light cluster would have a parking light LED, one for high beam, and an orange LED as indicator, all connected to a single WS2811. Similar on the left front.

On the left right another WS2811 would drive a red LED for combined tail/brake light function, an orange LED as indicator, and a white LED as reversing light. Repeat for rear right.

The four WS2811 devices are daisy-chained and the first WS2811 in the chain gets connected to the light controller.

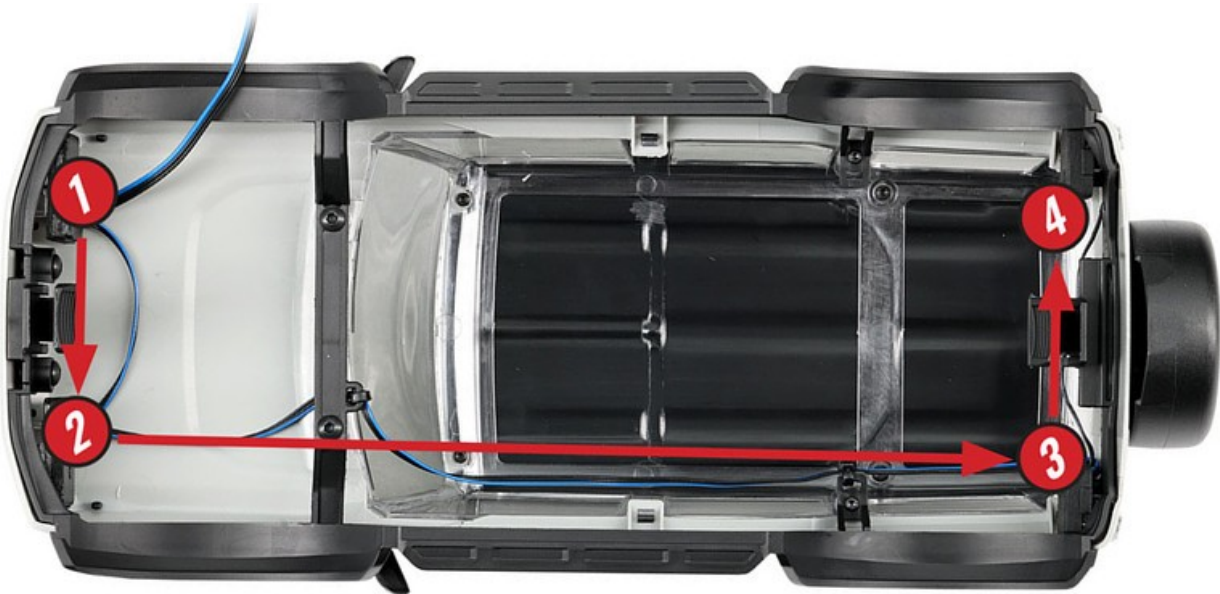


Image from Traxxas TRX-4M light kit documentation

The LEDs connected to the WS2811 IC can be controlled as *Slave* in the light controller configuration. When WS281x output is enabled, the first 15 *Slave* LEDs are mapped to the WS2811 chain. This implies that up to 5 WS2811 ICs can be used, each driving 3 LEDs for a total of 15 LEDs.

Animations and RGB LEDs

For more advanced LED configurations such as color LEDs and animations, it is possible to control the WS281x through **light programs**. *Light programs* are small scripts executed by the light controller. *Light programs* are available for Mk4, Mk4P and Mk4S since the inception, but now have been extended in this experimental firmware with functions for Addressable LEDs.

For a full documentation of the *light programs* including addressable LED functions please refer to the separate manual at <https://github.com/laneboysrc/rc-light-controller/blob/ws281x/mk4-tlc5940-lpc812/doc/light-programs-ws281x.md>

Light programs require a certain amount of programming skills. If you need assistance feel free to reach out to laneboysrc@gmail.com

WS281x device compatibility

To check whether a particular WS281x device is compatible with this experimental light controller firmware, we need to consult the data sheet of the WS281x intended to be used.

If there is no data sheet for your device, for example when purchasing random WS2812 LEDs from on-line shops, then there is no way to determine up-front whether the devices will work with this experimental firmware.

Supply voltage

Almost all WS281x devices are designed to operate at 5V and tolerate at most 5.5V. Unless your RC system (BEC, receiver) runs on 5V, a separate 5V voltage regulator is required.

Signal voltage of the DI line

The Data Input (DI) line of the WS281x requires certain voltages to determine whether a logic 0 or logic 1 is being transmitted.

For many WS281x devices the specification for a logic 1 signal on the DI line is a minimum voltage of $0.7 \times V_{DD}$. V_{DD} is the supply voltage of the WS281x device. At 5V, the DI line must have a voltage of no less than $0.7 \times 5V = 3.5V$ to be recognized as logic 1.

参数	符号	最小	典型	最大	单位	测试条件
输入电流	I_I	——	——	± 1	μA	$V_I = V_{DD}/V_{SS}$
高电平输入	V_{IH}	$0.7V_{DD}$	——	$V_{DD} + 0.7V$	V	D_{IN} , SET
低电平输入	V_{IL}	-0.3V	——	0.7V	V	D_{IN} , SET

Second row: Input High voltage must be at least $0.7V_{DD}$

The micro-controller in light controller operates at 3.3V. This means that it can output at most 3.3V, which is below the minimum that many WS281x accepts as logic 1.

For such devices a level-shifter is required, which converts the 3.3V logic to 5V logic. Note that the level-shifter must support data rates of at least 5 MHz.

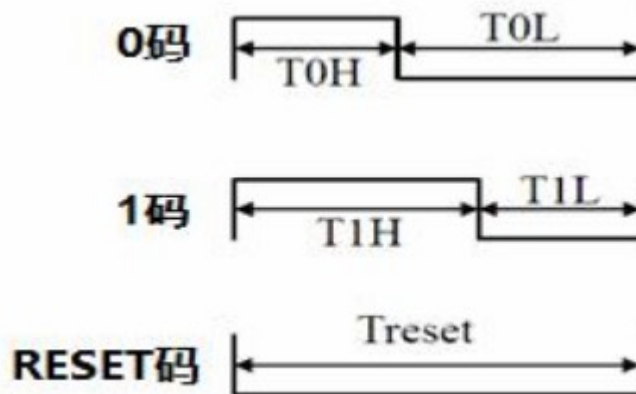
Some WS281x devices are designed to work with 3.3V logic. For example the *Worldsemi WS2812C-2020-V1* RGB LED requires only 2.7V for logic 1.

参数	符号	最小	典型	最大	单位	测试条件
输入电流	I_I	—	—	± 1	μA	$V_I = V_{DD}/V_{SS}$
高电平输入	V_{IH}	2.7V	—	$V_{DD} + 0.7V$	V	D_{IN} , SET
低电平输入	V_{IL}	-0.3V	—	0.7V	V	D_{IN} , SET

Second row: Input High voltage must be larger than 2.7V, hence is suitable to be driven by 3.3V devices

Timing protocol

The basic WS281x protocol is always the same, but the timing values differ between various specific devices.



Timing diagram as shown in the WS8211 datasheet

There are 5 timing values relevant for the protocol.

T0H: the time the DI line is **high** when transmitting a logic **0** data bit

T0L: the time the DI line is **low** when transmitting a logic **0** data bit

T1H: the time the DI line is **high** when transmitting a logic **1** data bit

T1L: the time the DI line is **low** when transmitting a logic **1** data bit

Reset: the time that indicates to the WS281x device that a packet has been completed

The light controller outputs the following timing values:

T0H: 250ns

T0L: 750ns

T1H: 750ns

T1L: 250ns

Reset: >1ms

These values are suitable for the WS2811 device, for which the datasheet requires:

T0H: 220-380ns

T0L: 580-1000ns
T1H: 580-1000ns
T1L: 220-420ns

The WS2812C-2020-V1 datasheet states different requirements:

T0H: 220-380ns
T0L: 580-1000ns
T1H: 580-1000ns
T1L: 580-1000ns

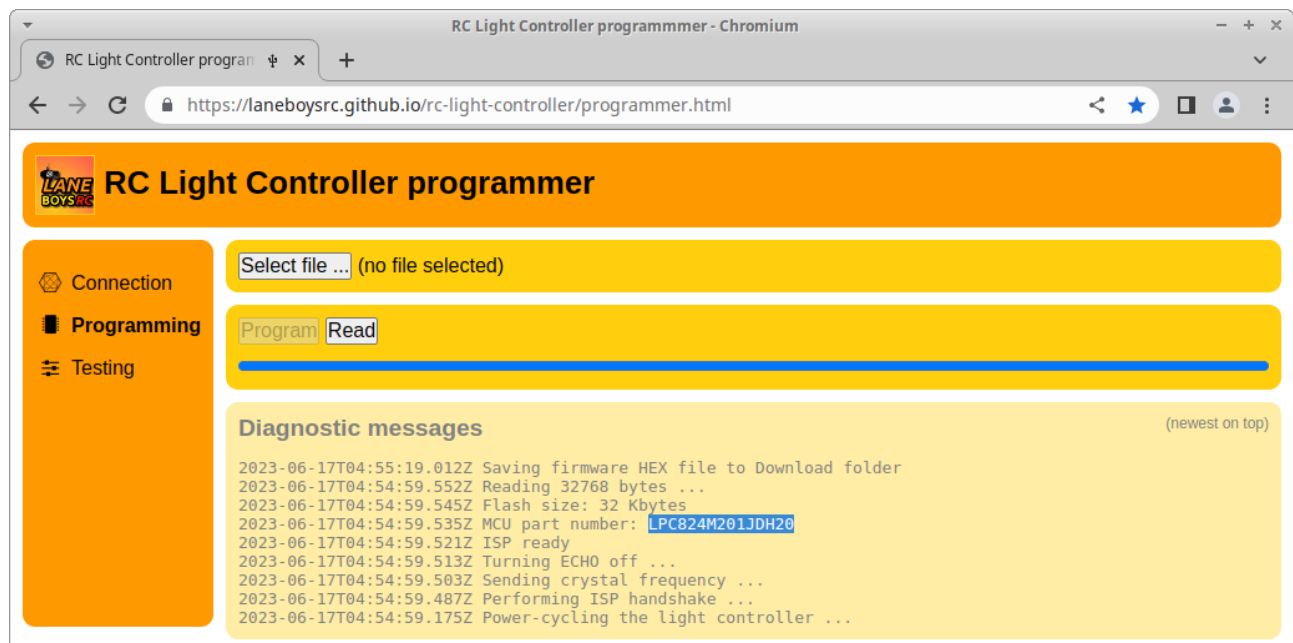
However, testing showed that the WS2812C-2020-V1 still works fine with the experimental firmware, despite T1L being outside of the specification.

Verify if your light controller is suitable to run the Addressable LED firmware

Due to the increased size of the firmware, only light controllers built from 2022 onward using the NXP LPC824 micro-controller can be used.

You can check with your light controller has the correct micro-controller using the following steps:

- Load <https://laneboysrc.github.io/rc-light-controller/programmer.html>
- Connect the light controller to your WebUSB programmer
- Press the Read button
- In the diagnostics window look for the following information



If MCU part number says anything else than **LPC824M201JDH20** (e.g. LPC812 or LPC832) then your light controller is not compatible with this experimental firmware.

Source code

The experimental software for Addressable LEDs is kept in a separate *branch* named **ws281x** in the Github repository of the light controller.

It can be accessed through the following link:

<https://github.com/laneboysrc/rc-light-controller/tree/ws281x>