# DALI LED Driver Control System for Lighting Operations Based on Raspberry Pi and Kernel Modules

Group: Hello World

Instructor: Minh-Huan Vo

# Team members

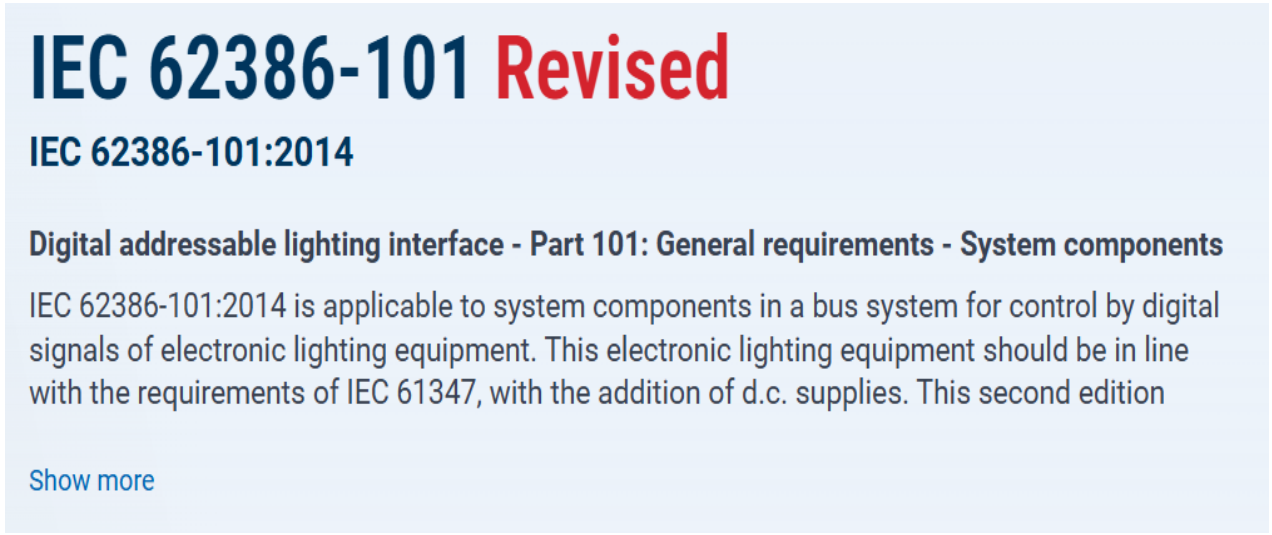
| | |
|---|---|
| Lê Thành Ngân | 22139044 |
| Huỳnh Phước Long | 22139037 |
| Ngô Khải Hoàng | 22139024 |
| Huỳnh Xuân Vỹ | 22139079 |
| Trần Duy Vương | 22139078 |
| Lê Thành Tài | 22139057 |
| Lưu Ngọc Thiện | 22139065 |
| Võ Minh Thái | 22139063 |
| Ngô Đình Thái Long | 22139038 |

# Introduction

1. General introduction to the project — Phước Long
2. Hardware components utilized in the DALI LED driver control system — Xuân Vỹ
3. DALI Protocol - structure and advantages — Minh Thái
4. Manchester encoding — Duy Vương
5. Software architecture and control modules — Thành Tài
6. User interface & application — Thành Ngân & Khải Hoàng
7. Result of the project — Ngọc Thiện
8. Comparison with similar systems — Thái Long
9. Experimental setup & results — Thành Tài

# General introduction to the project

1. What is the Digital Addressable Lighting Interface (DALI)?




An international standard protocol (IEC 62386) for controlling lighting systems.

# General introduction to the project

## 2. Features of DALI in the current age

- **Addressability:** Controls individual lights
- **Two-way communication:** Monitors device status
- **Energy efficiency:** Reduces power usage.
- **Scalability:** Expands for any additional system
- **Diverse application:** Adapts to residential, commercial, and industrial lighting

# General introduction to the project

## Why choose Raspberry Pi 5?

| CPU Test Suite Average Results for ARM Cortex-A72 4 Core 1500 MHz | |
|---|---|
| Integer Math | 6,839 MOps/Sec |
| Floating Point Math | 3,318 MOps/Sec |
| Find Prime Numbers | 2 Million Primes/Sec |

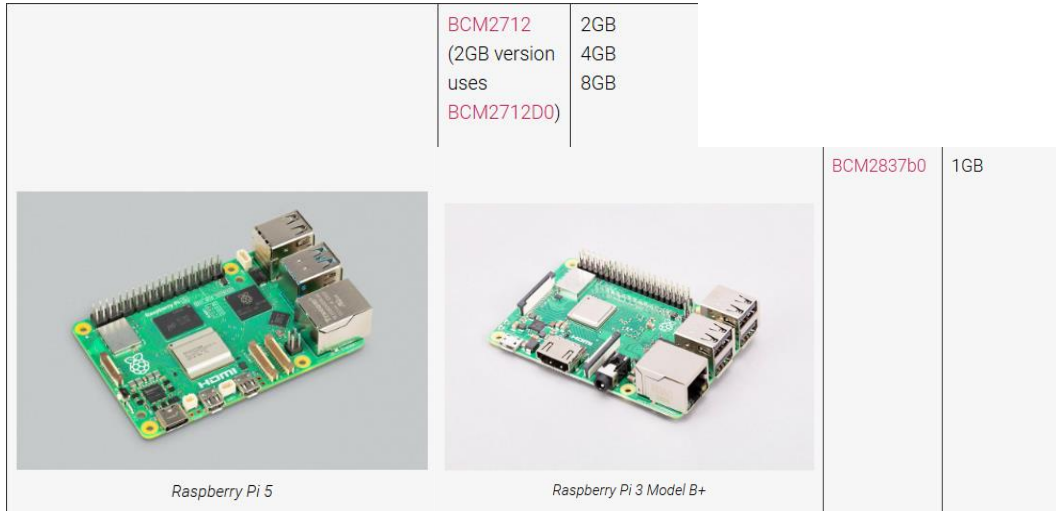
*CPU of RPi3*

| CPU Test Suite Average Results for ARM Cortex-A76 4 Core 2400 MHz | |
|---|---|
| Integer Math | 14,581 MOps/Sec |
| Floating Point Math | 11,311 MOps/Sec |
| Find Prime Numbers | 6 Million Primes/Sec |

*CPU of RPi5*

Compare RPi5 to lower raspberry version:

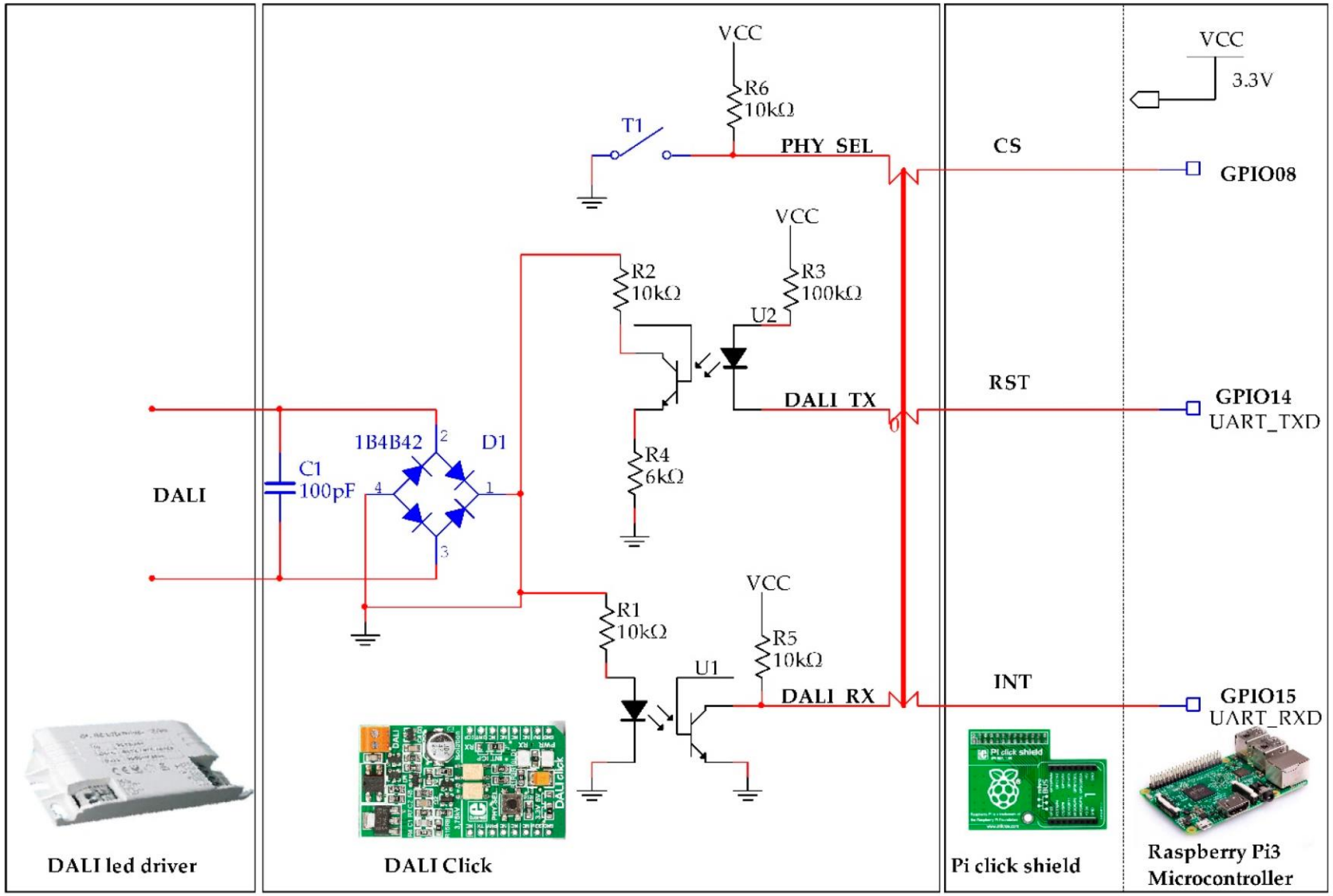
- Efficiency: CPU of RPi5 is powerful
- Memory: RPi5 is enough for DALI systems and any other additional functions



# Function of Raspberry Pi

- **DALI Signal Interface**: Utilizes GPIO14 and GPIO15 for sending and receiving DALI signals.
- **Manchester En-Decoding**: Encodes and decodes DALI signals, enabling remote brightness adjustment of LEDs.
- **Kernel Driver Operation**: Implements a kernel driver that allows the system to interface with GPIO hardware, integrating Raspberry Pi into the lighting control system.

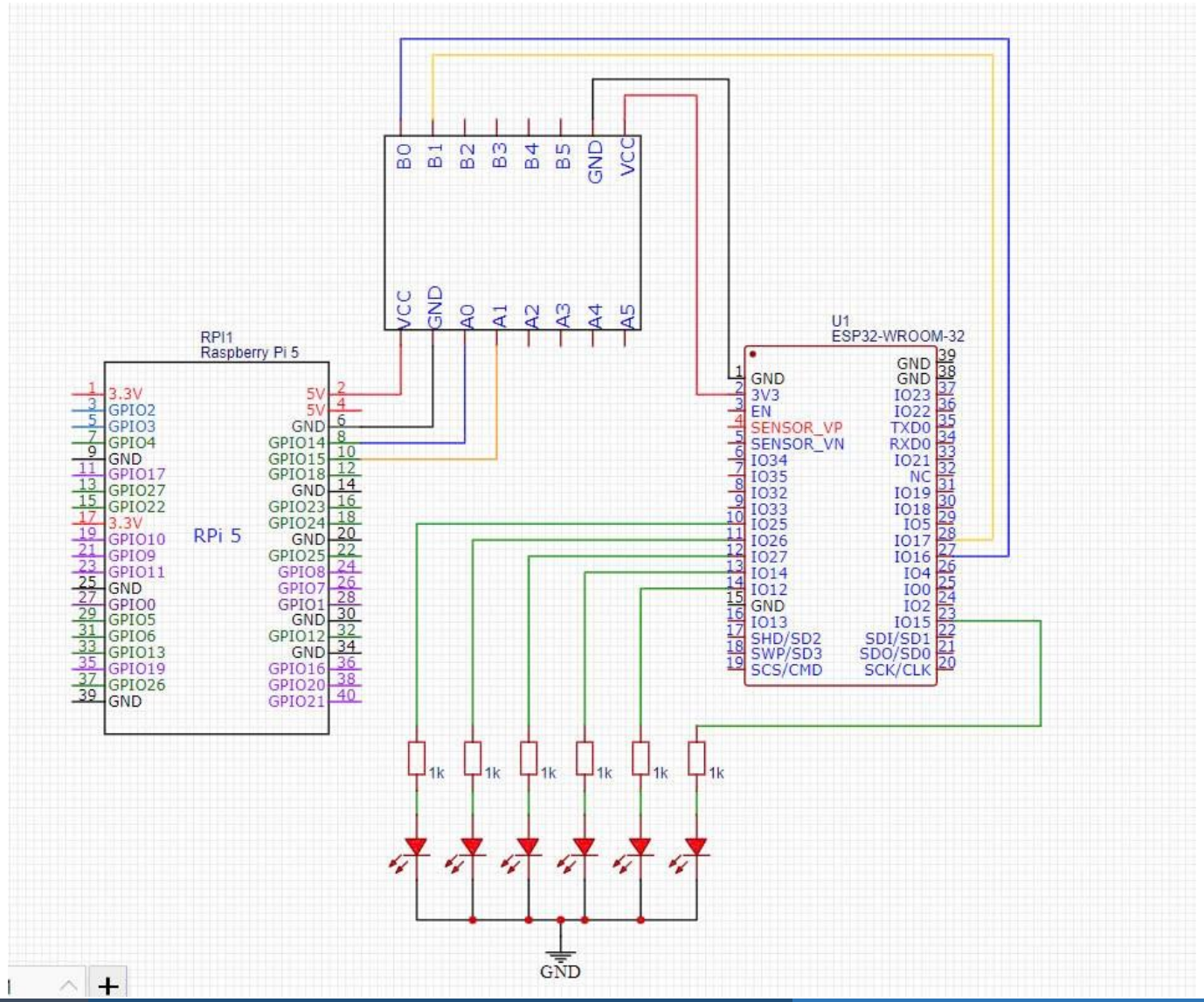
# Hardware


VCC
R6
10kΩ
T1
PHY SEL
CS
VCC
3.3V
GPIO08
VCC
R2
10kΩ
R3
100kΩ
U2
DALI TX
RST
GPIO14
UART_TXD
R4
6kΩ
1B4B42
D1
C1
100pF
DALI
VCC
R1
10kΩ
R5
10kΩ
U1
DALI RX
INT
GPIO15
UART_RXD
DALI led driver
DALI Click
Pi click shield
Raspberry Pi3
Microcontroller

# Function of ESP32

- **DALI Signal Interface**: Utilizes GPIO16 (In) and GPIO17 (Out) for sending and receiving DALI signals.
- **LED Control**: Adjusts the brightness of LEDs via PWM on GPIO pins (12, 14, 15, 25, 26, 27).
- **Signal Processing**: Converts binary signals into LED control information, mapping values from 0-255 to 0-1023.

# Wiring Diagram



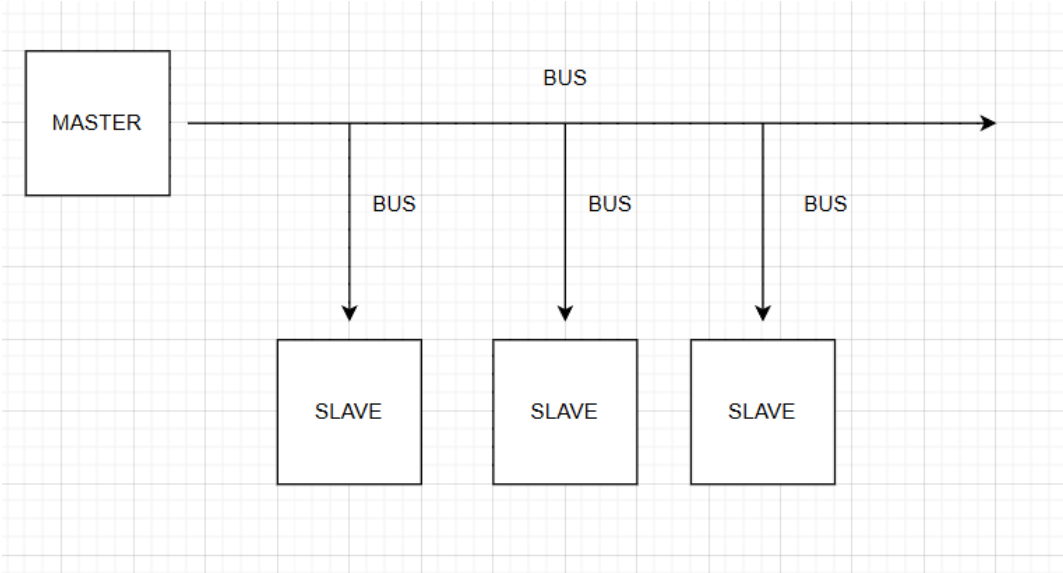
# The DALI protocol

1. Used two wire low-voltage serial bus
2. Data tranfer rate: 1200 bps

3. Range 9.5 to 22.5 voltage (typical 16V) is know that high signal

4. Range 6.5 to 0 voltage (Typical 0V) is know that low signal

DALI protocol base on master-slave principle




Up to 64 devices

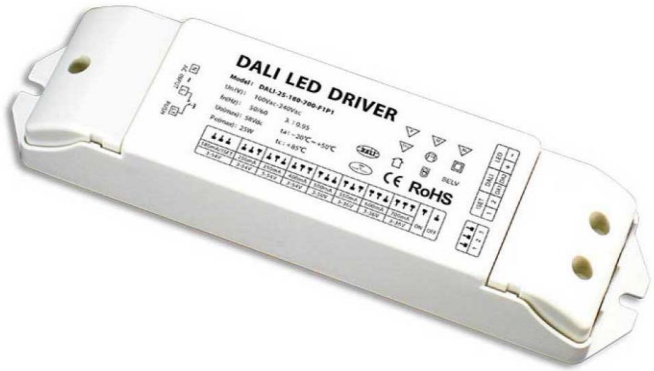
# The DALI protocol

In this project

1. Data tranfer rate: 0.01s per Manchester encoded bit

2. Range 2.4 to 3.3 voltage  is know that high signal

3. Range 0 to 0.8 voltage  is know that low signal




# The DALI protocol

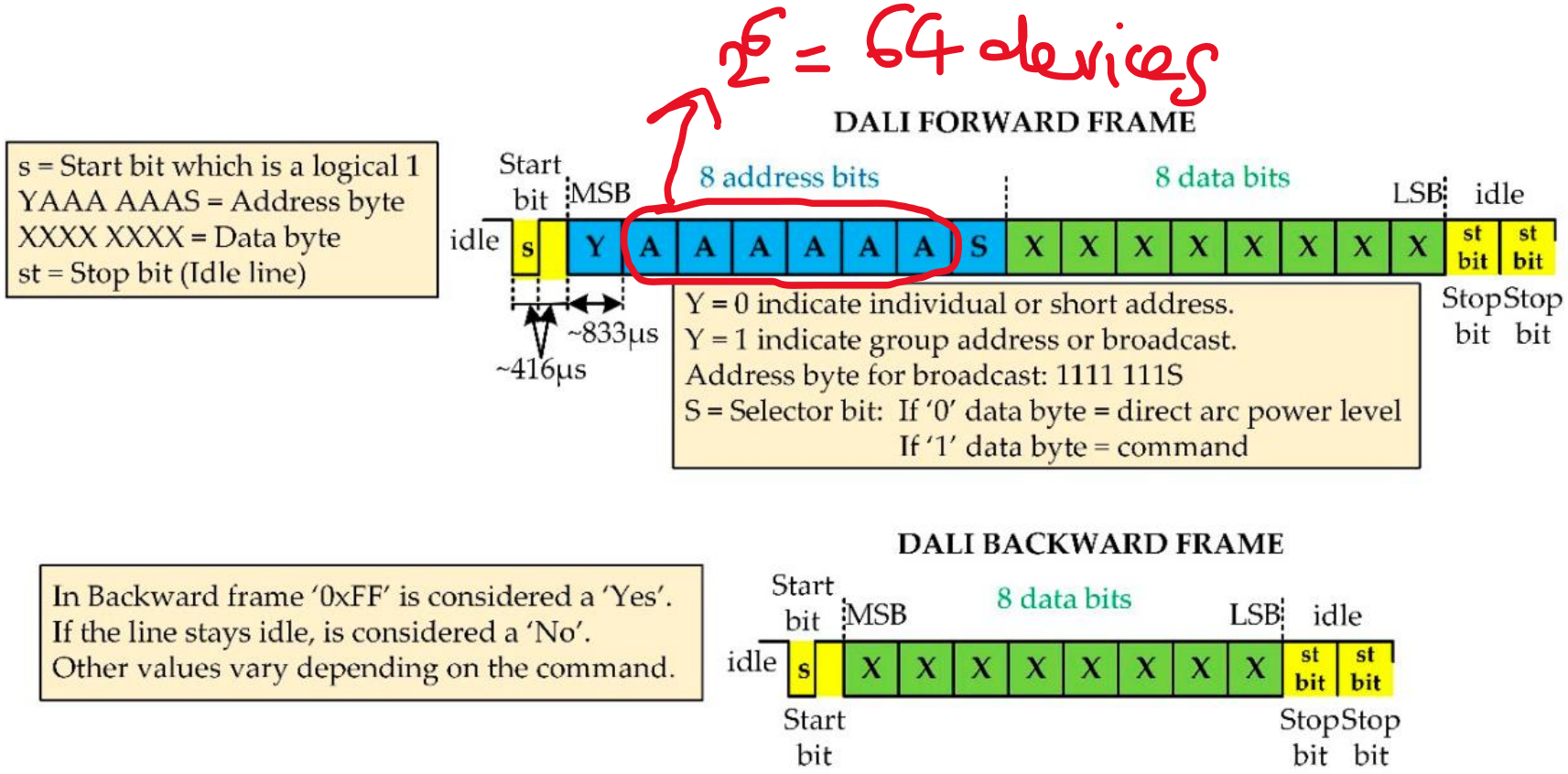



**Figure 1.** Digital Addressable Lighting Interface (DALI) protocol two-way communication message structure (forward & backward frames).

Manchester encoding?

# Advantages

1. Precise control of each device

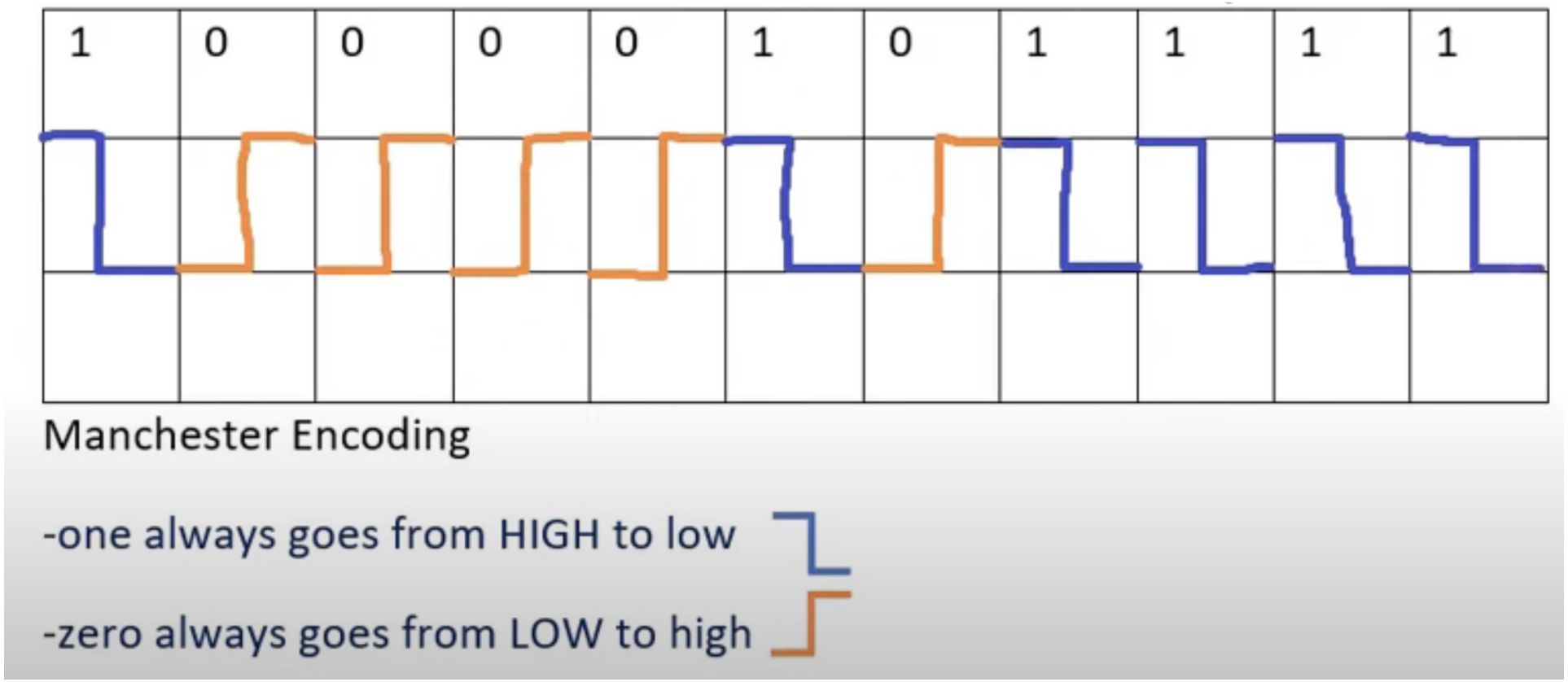
2. Device status feedback capability

3. Global standardization and high compatibility

4. Flicker-free dimming

5. Simple implementation with straightforward wiring requirements

# Manchester encoding




- Widely used in Ethernet, telecommunications, and digital data transmission systems.

# Advantages of Manchester encoding

**Self-Synchronization**: Each bit has a midpoint transition, eliminating the need for an external clock and simplifying connections.
**Error Detection**: Reliable transitions allow quick identification of errors, crucial for precise lighting control.
**Minimal DC Offset**: Frequent transitions maintain signal integrity over long cables, suitable for DALI's environment.
**Low-Speed Compatibility**: Works well at DALI’s low data rates, ensuring consistent signal quality.
**Cost Efficiency**: Simplifies circuitry, reducing overall costs for scalable and low-maintenance lighting systems.

# Illustrate Manchester encoding

```
[14233.324262] gpio_stringout = 026113
[14233.324270] igpio_stringout[0] (address) = 26
[14233.324273] igpio_stringout[1] (data) = 113
[14233.324275] Executing the write function
[14233.324284] Start timer
[14233.324287] Timer started
[14233.334290] Bit value OUT is 1   start bit
[14233.344288] Bit value OUT is 0
[14233.354297] Bit value OUT is 0
[14233.364293] Bit value OUT is 1
[14233.374289] Bit value OUT is 0
[14233.384290] Bit value OUT is 1
[14233.394289] Bit value OUT is 0
[14233.404288] Bit value OUT is 1
[14233.414289] Bit value OUT is 1   address
[14233.424288] Bit value OUT is 0
[14233.434288] Bit value OUT is 1
[14233.444288] Bit value OUT is 0
[14233.454288] Bit value OUT is 0
[14233.464288] Bit value OUT is 1
[14233.474288] Bit value OUT is 1
[14233.484288] Bit value OUT is 0
[14233.494289] Bit value OUT is 0
[14233.504288] Bit value OUT is 1
[14233.514288] Bit value OUT is 0
[14233.524288] Bit value OUT is 1
[14233.534287] Bit value OUT is 1
[14233.544288] Bit value OUT is 0
[14233.554290] Bit value OUT is 1
[14233.564290] Bit value OUT is 0
[14233.574287] Bit value OUT is 1   data
[14233.584288] Bit value OUT is 0
[14233.594287] Bit value OUT is 0
[14233.604287] Bit value OUT is 1
[14233.614288] Bit value OUT is 0
[14233.624288] Bit value OUT is 1
[14233.634288] Bit value OUT is 0
[14233.644287] Bit value OUT is 1
[14233.654288] Bit value OUT is 1
[14233.664288] Bit value OUT is 0
[14233.674287] Bit value OUT is 1
[14233.684288] Bit value OUT is 1   stop bit
[14233.694287] Bit value OUT is 1
[14233.704287] Bit value OUT is 1
```

Manchester Encoding

Address: 26

Data: 113

Send Command

1:

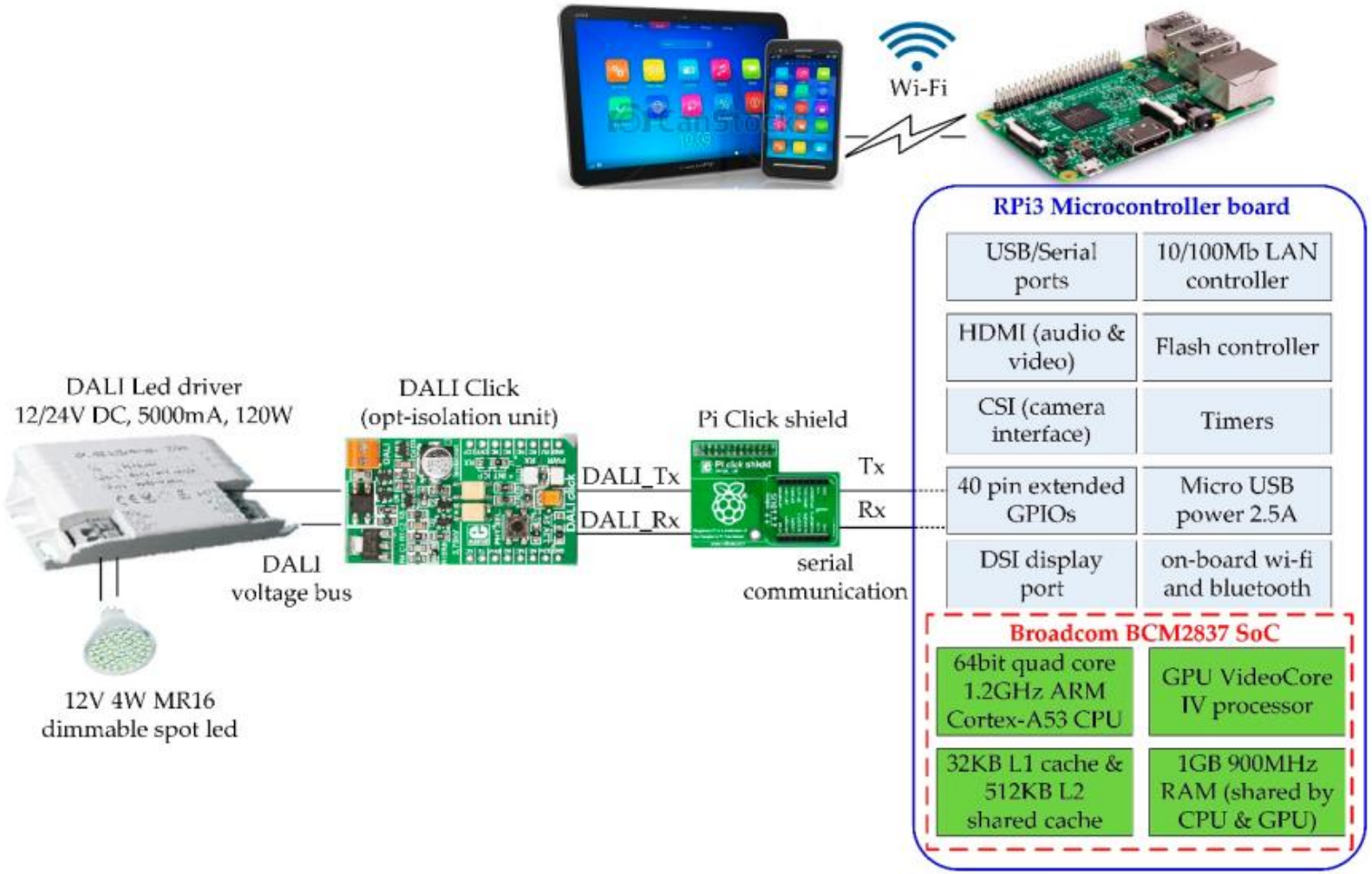
0:

Start Bit | Address : 26 | Data : 113 | Stop Bit

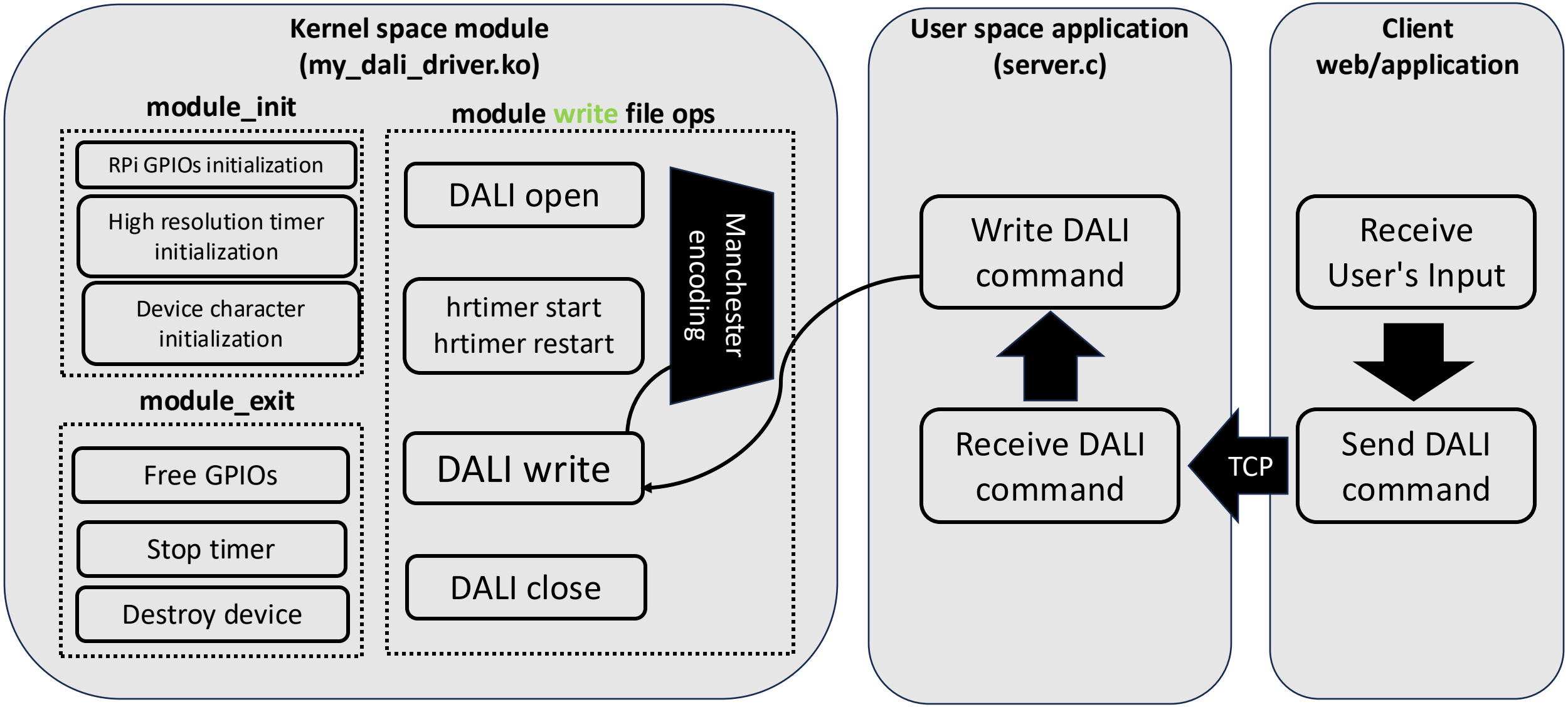
1 0 0 0 1 1 0 1 0 0 1 1 1 0 0 0 1

10 01 01 01 10 10 01 10 01 01 10 10 01 01 01 10 11

# Software Architecture



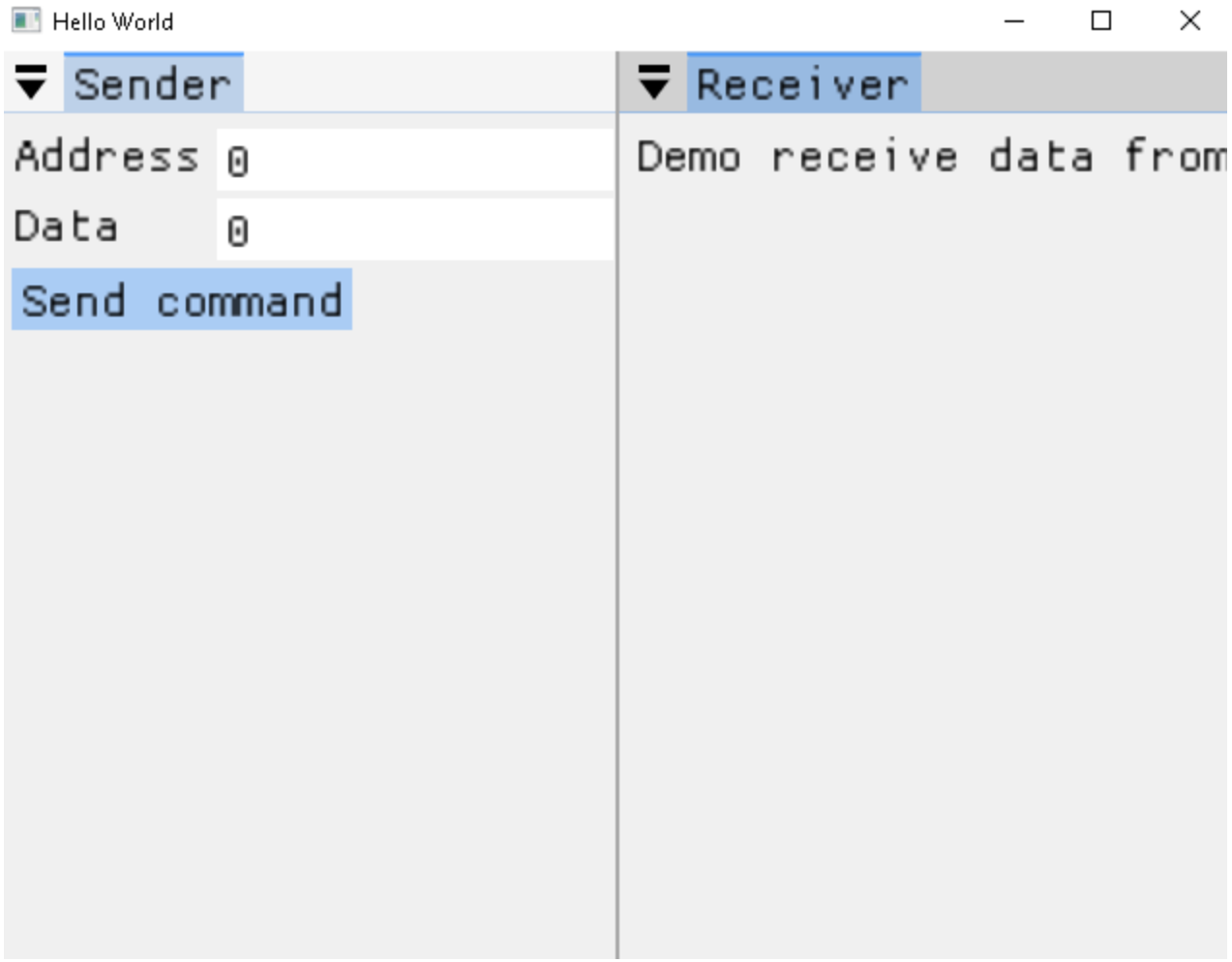
# Software Architecture



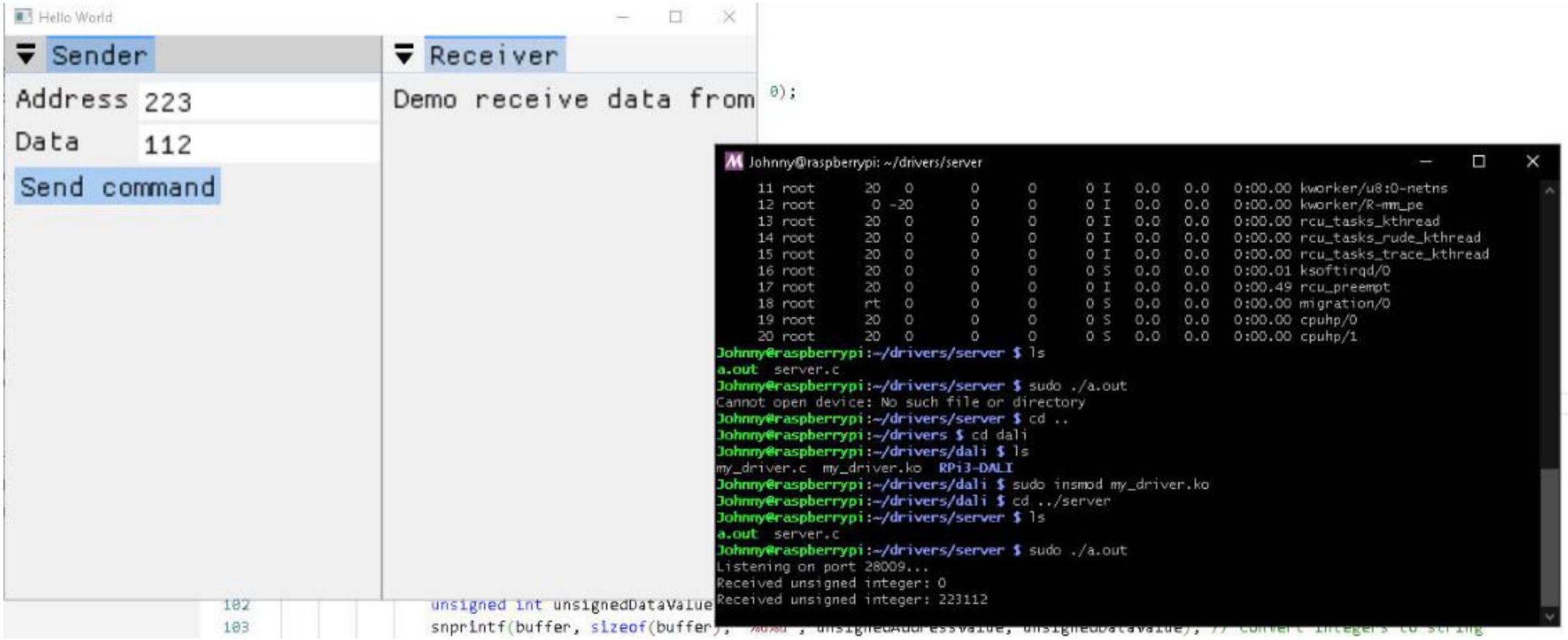
# User interface & application

- The user-space application runs as a server, using TCP to receive commands, enabling flexibility to develop applications across various platforms without platform-specific dependencies.
- The demo client application is programmed in C++ and uses GLFW, OpenGL, and the ImGui library to create an interactive environment.
- Additionally, a web client can also be used to send commands directly to our Raspberry Pi 5 server

# User interface & application

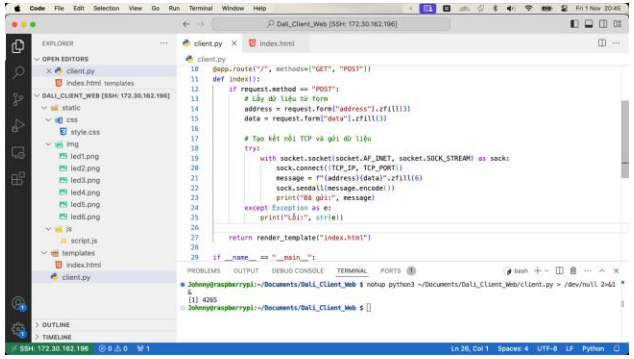


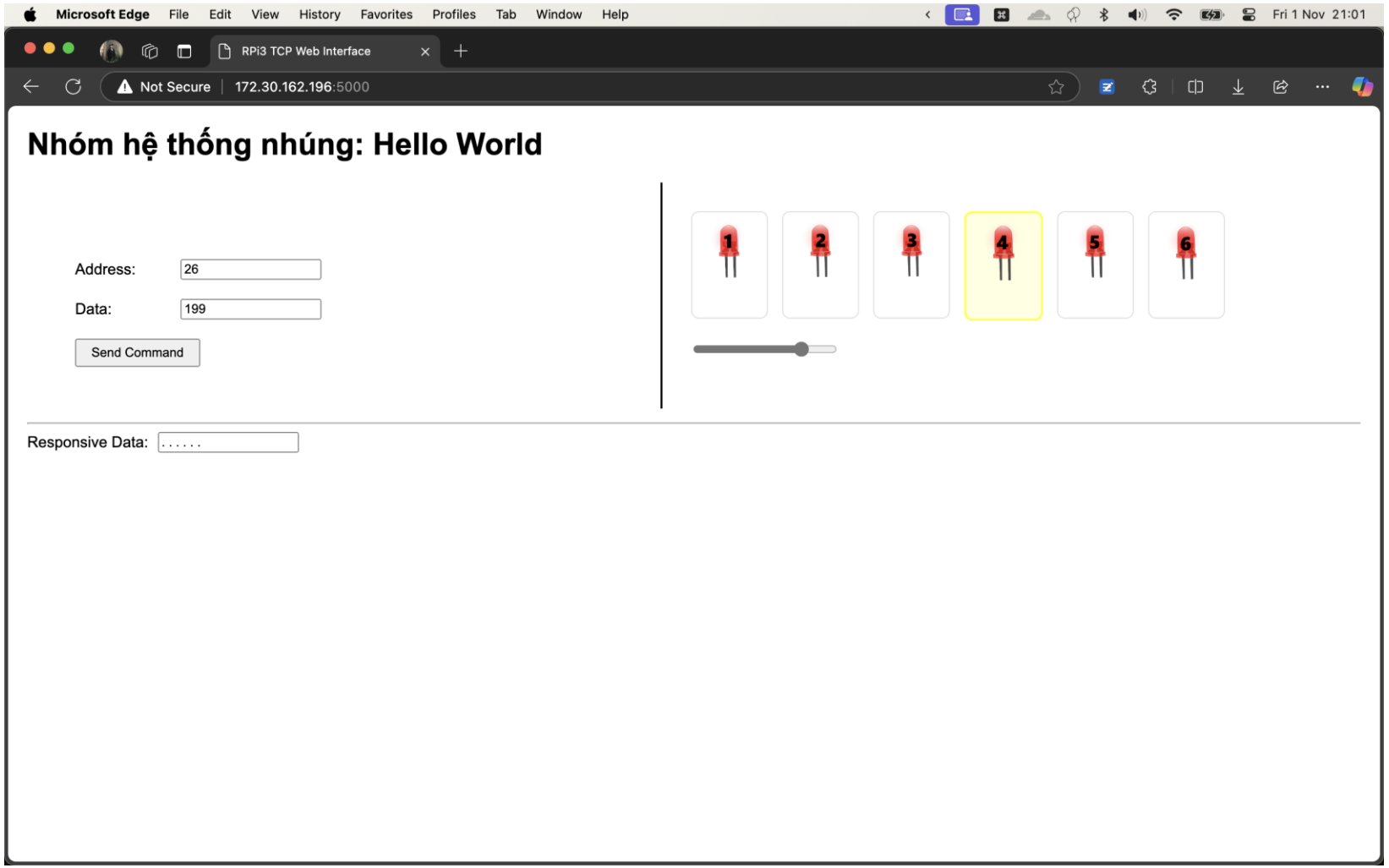
# User interface & application



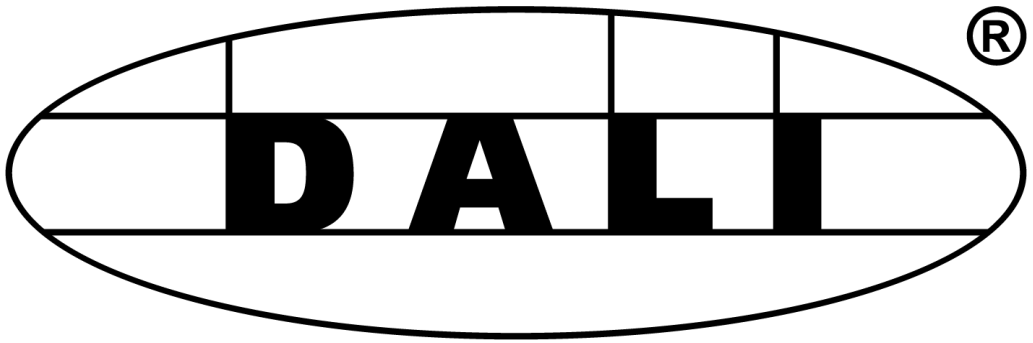
# Web App (server Flask)

http://172.30.162.196:5000/





# Comparison with Similar Systems




| | DALI (Digital Addressable Lighting Interface) |
|---|---|
| **Main Application** | Energy-efficient, flexible, and programmable building and industrial lighting control |
| **Connection Type** | 2-wire bus system |
| **Dimming Control** | Smooth dimming, with support for color control in DALI-2 |
| **Transmission Speed** | 1,200 bps (and up to 9.6 kbps in DALI-2) |
| **Power Consumption** | Low, energy-saving |
| **Control Range** | 300 meters per segment |
| **Cost** | Moderate, suitable for industrial use |
| **Security** | Basic security, may require more for remote or networked access |

# Comparison with Similar Systems


| | DMX (Digital Multiplex) | DALI (Digital Addressable Lighting Interface) |
|---|---|---|
| **Main Application** | Primarily used in stage, theatrical, and event lighting | Energy-efficient, flexible, and programmable building and industrial lighting control |
| **Connection Type** | 3-wire or 5-wire XLR cable | 2-wire bus system |
| **Dimming Control** | Synchronized color, intensity adjustment | Smooth dimming, with support for color control in DALI-2 |
| **Transmission Speed** | 250 kbps, real-time synchronization | 1.2 kbps (and up to 9.6 kbps in DALI-2) |
| **Power Consumption** | Higher than Zigbee & Dali suitable for high-power lights | Low, energy-saving |
| **Control Range** | Around 100 meters can be extended with signal boosters | 300 meters per segment |
| **Cost** | Higher, ideal for professional use | Moderate, suitable for industrial use |
| **Security** | Low and generally not prioritized | Basic security, may require more for remote or networked access |

# Comparison with Similar Systems

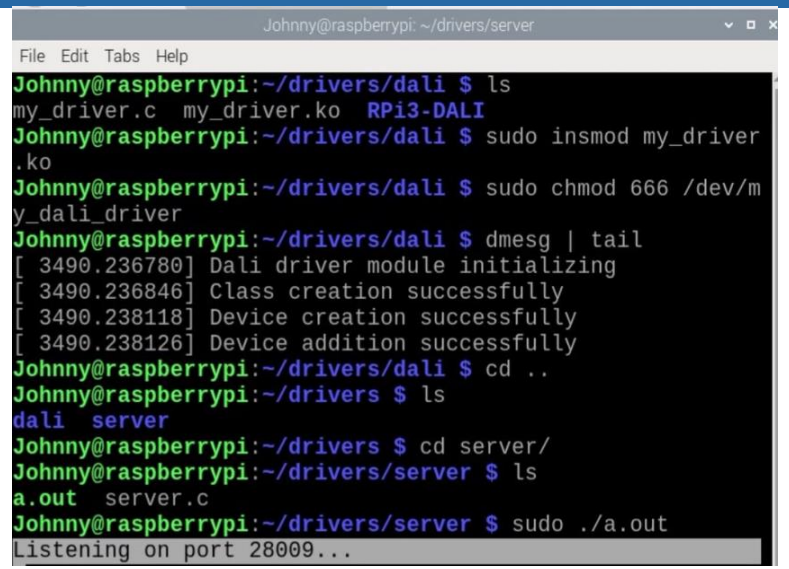

| | Zigbee | DALI (Digital Addressable Lighting Interface) |
|---|---|---|
| **Main Application** | Smart home and residential lighting | Energy-efficient, flexible, and programmable building and industrial lighting control |
| **Connection Type** | Wireless (IEEE 802.15.4 standard) | 2-wire bus system |
| **Dimming Control** | Smooth dimming and color tuning | Smooth dimming, with support for color control in DALI-2 |
| **Transmission Speed** | At 250 kbps, wireless | 1.2 kbps (and up to 9.6 kbps in DALI-2) |
| **Power Consumption** | Very low, optimized for energy efficiency | Low, energy-saving |
| **Control Range** | Up to 100 meters wireless, Can extend using Relay signals | 300 meters per segment |
| **Cost** | Low to moderate, ideal for home use | Moderate, suitable for industrial use |
| **Security** | Good, including AES 128-bit encryptionn | Basic security, may require more for remote or networked access |

# Comparison with Similar Systems

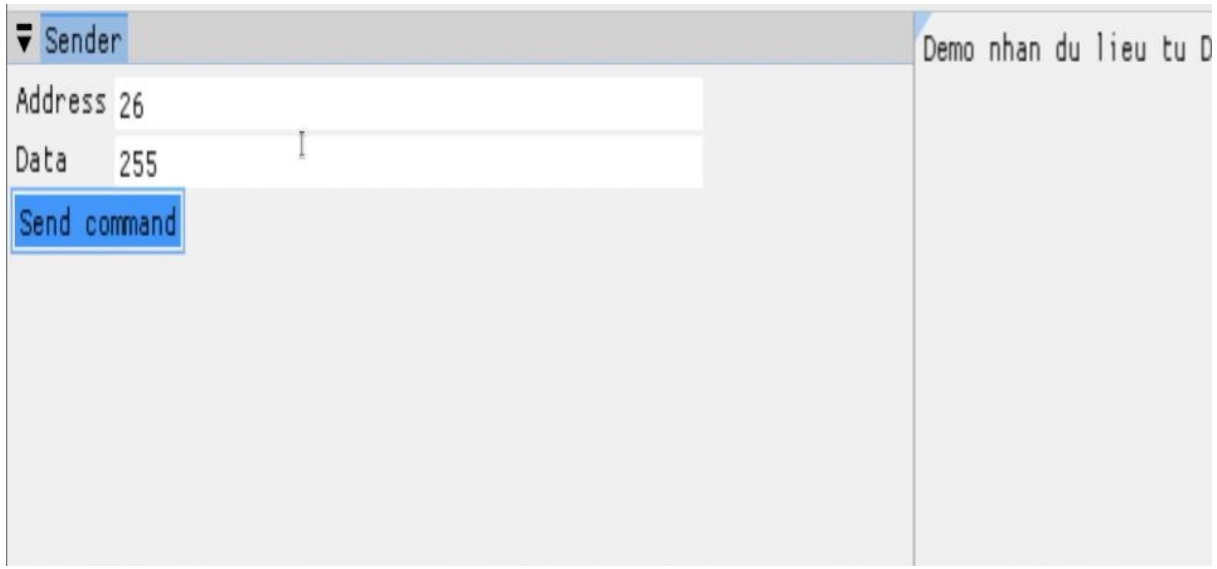

| | KNX (KONNEX) | DALI (Digital Addressable Lighting Interface) |
|---|---|---|
| **Main Application** | Complex systems that control many building functions | Energy-efficient, flexible, and programmable building and industrial lighting control |
| **Connection Type** | Wired (bus cable), can be wireless | 2-wire bus system |
| **Dimming Control** | Dimming, on/off control | Smooth dimming, with support for color control in DALI-2 |
| **Transmission Speed** | 9.6 kbps, suitable for building automation but not real-time applications | 1.2 kbps (and up to 9.6 kbps in DALI-2) |
| **Power Consumption** | Moderate, often powered via the KNX bus | Low, energy-saving |
| **Control Range** | Up to 1,000 meters | 300 meters per segment |
| **Cost** | Higher installation cost, suitable for commercial buildings | Moderate, suitable for industrial use |
| **Security** | High, multiple security levels | Basic security, may require more for remote or networked access |

| | DALI (Digital Addressable Lighting Interface) | DMX (Digital Multiplex) | Zigbee | KNX (Konnex) |
|---|---|---|---|---|
| **Main Application** | Building and industrial lighting control | Stage and event lighting | Smart home and residential lighting | Building automation |
| **Connection Type** | Wired (2-wire bus system) | Wired (3-wire/5-wire system) | Wireless (IEEE 802.15.4) | Wired (bus cable), can be wireless |
| **Dimming Control** | Smooth dimming, supports color tuning | Synchronized color, intensity adjustment | Adjustable brightness, color tuning | Dimming, on/off control |
| **Transmission Speed** | Slower | High-speed, real-time | Moderate | Moderate |
| **Power Consumption** | Low | High | Very low | Low |
| **Control Range** | ~300 meters per line | ~100 meters per line | ~100 meters wireless | ~1,000 meters per line |
| **Cost** | Moderate, suitable for industrial use | Highest, ideal for professional use | Low to moderate, ideal for home use | High, suitable for commercial buildings |
| **Security** | Relatively secure, may need added encryption | Low security, not essential for stage use | Moderate, AES wireless encryption | High, multiple security levels |

# Result of the project







# Result of the project

```
[14995.912838] gpio_stringout = 026255
[14995.912845] igpio_stringout[0] (address) = 26
[14995.912847] igpio_stringout[1] (data) = 255
[14995.912849] Executing the write function
[14995.912856] Start timer
[14995.912859] Timer started
[14995.922862] Bit value OUT is 1
[14995.932860] Bit value OUT is 0
[14995.942874] Bit value OUT is 0
[14995.952862] Bit value OUT is 1
[14995.962862] Bit value OUT is 0
[14995.972862] Bit value OUT is 1
[14995.982862] Bit value OUT is 0
[14995.992859] Bit value OUT is 1
[14996.002859] Bit value OUT is 1
[14996.012861] Bit value OUT is 0
[14996.022860] Bit value OUT is 1
[14996.032859] Bit value OUT is 0
[14996.042859] Bit value OUT is 0
[14996.052861] Bit value OUT is 1
[14996.062860] Bit value OUT is 1
[14996.072861] Bit value OUT is 0
[14996.082860] Bit value OUT is 0
[14996.092860] Bit value OUT is 1
[14996.102860] Bit value OUT is 1
[14996.112860] Bit value OUT is 0
[14996.122860] Bit value OUT is 1
[14996.132860] Bit value OUT is 0
[14996.142860] Bit value OUT is 1
[14996.152860] Bit value OUT is 0
[14996.162860] Bit value OUT is 1
[14996.172860] Bit value OUT is 0
[14996.182860] Bit value OUT is 1
[14996.192860] Bit value OUT is 0
[14996.202860] Bit value OUT is 1
[14996.212860] Bit value OUT is 0
[14996.222861] Bit value OUT is 1
[14996.232861] Bit value OUT is 0
[14996.242861] Bit value OUT is 1
[14996.252860] Bit value OUT is 0
[14996.262860] Bit value OUT is 1
[14996.272861] Bit value OUT is 1
[14996.282860] Bit value OUT is 1
[14996.292860] Bit value OUT is 1
```