Buce: 6-Channel All-in-One WiFi LED PWM Controller

Features

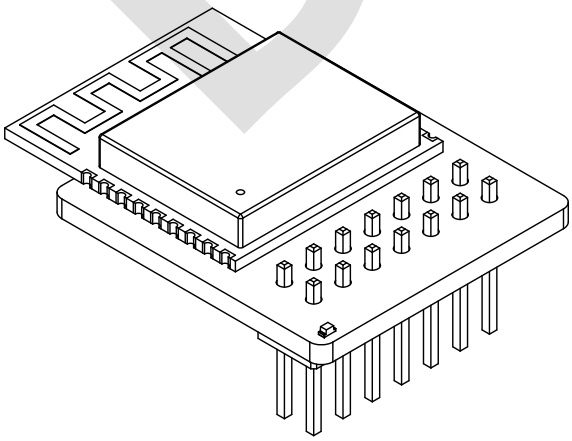
- Highly integrated all-in-one 6-channel WiFi LED PWM controller
- Supports advanced LED lighting functions such as timed on/off, sunrise/sunset, and multi-segment dimming via mobile app
- Wide voltage range: 15 V to 36 V
- Configurable PWM dimming frequency (default 24 kHz)
- **4096 dimming levels**, supports phase shifting for the PWM signals
- Built-in NTC support circuit and reference voltage source
- Fan voltage regulation based on PID algorithm, capable of directly driving 12 V fans for speed control
- Supports PWM fans
- Built-in power supply voltage monitoring
- Supports external INA139 for current monitoring
- Safety features such as automatic overheat shutdown
- 3.3 V output for peripheral circuits
- Compact design with dimensions of 2.2×30mm
- Fully open-sourced

Overview

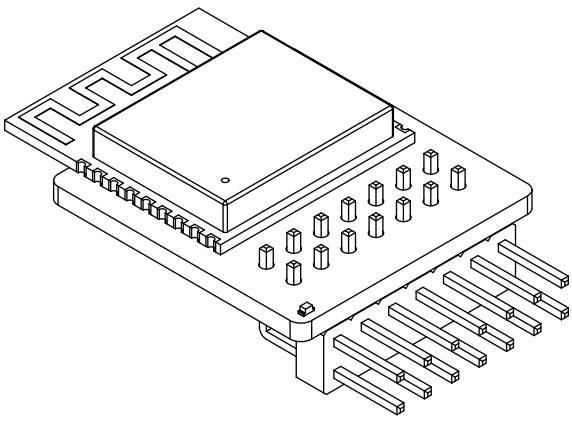
The Buce (Model BLC06MK1) is an innovative embedded 6-channel all-in-one WiFi LED PWM (Pulse-Width Modulation) controller module designed for high-power LED lighting. It features six independent PWM dimming channels, allowing users to customize and control lighting effects wirelessly through our open-source phone app. With multi-segment dimming capabilities, this module can simulate natural daylight transitions, such as sunrise and sunset, enhancing the visual experience in various settings.

Applications

- Smart high-power aquarium LED
- Agricultural LED applications
- Beauty devices
- Home lighting or ambient LEDs
- Photography lighting



DIP-14 Vertical Pin Header



DIP-14 90° Pin Header

Contents

1. Hardware Specifications

1.1. Pin Definition and Functions

Figure 1 shows the appearance of the Buce module. Other variant have similar dimensions.

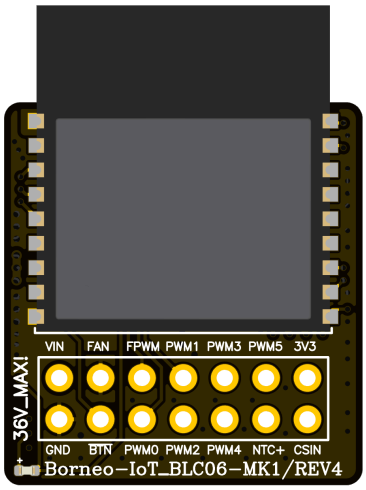


Figure 1: Appearance Diagram

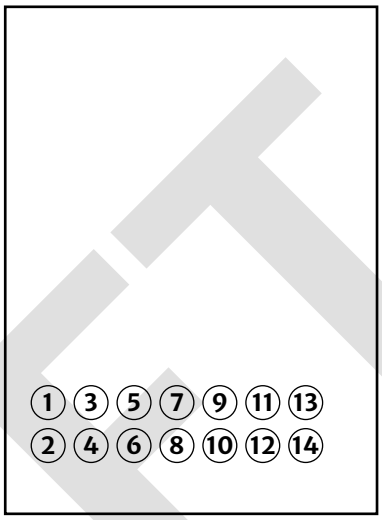


Figure 2: Pinout Diagram

All Buce family modules share the same pin definitions. The pin order refers to Figure 2, and the functions refer to Table 1.

Table 1: Pinout Table

Pin #	Name	Type	Description
1	VIN+	Power Input	15 36 V Main Power Input
2	GND	—	Ground, 0 V
3	FAN+	Power Output	+12 V Fan drive output[1]
4	$\overline{\text{BTN}}$	Input	Button input
5	FAN_PWM	Output	Fan PWM signal output for speed control
6	PWM0	Output	Channel 0 PWM Signal Output
7	PWM1	Output	Channel 1 PWM signal output
8	PWM2	Output	Channel 2 PWM signal output
9	PWM3	Output	Channel 3 PWM signal output
10	PWM4	Output	Channel 4 PWM signal output
11	PWM5	Output	Channel 5 PWM signal output
12	NTC+	Input	3950 10 kΩ NTC input
13	+3V3	Power Output	+3.3 V output
14	CSEN	Input	INA139 current monitor input

[1]When using two-wire fan mode, this voltage varies from 3.5 V to 12 V for speed control. When using PWM fan mode, it is fixed at 12 V.

1.2. Programming Port

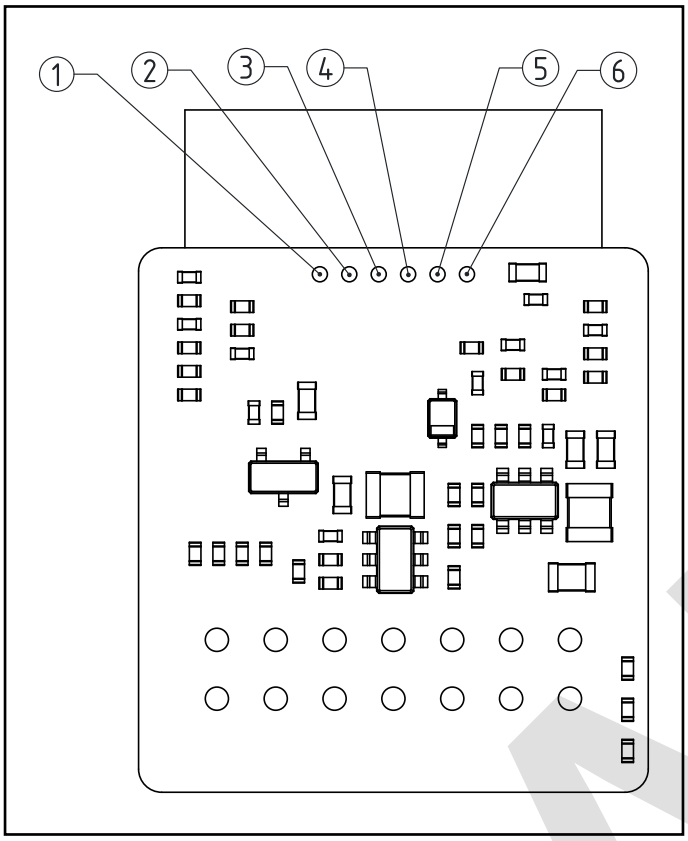


Figure 3: Diagram of the Programming Port on the Back

As shown in Figure 3, the programming port is located at the top of the back side of the module PCB. It is used for debugging, firmware flashing, and initial configuration. Its functions and definitions are listed in Table 2.

For details on using the programming port, please refer to Section 3.1.2.

Table 2: Programming Port Pinout Table

Pin #	Name	Type	Description
1	GND	—	Ground, 0 V
2	$\overline{\text{PROG/BTN}}$	Input	Low level sets module to programming mode, high level or floating for normal boot[2]
3	$\overline{\text{RST}}$	Input	Module reset pin, low level resets
4	UART0_TX	Output	Module UART0 TX, connect to programmer RX
5	UART0_RX	Input	Module UART0 RX, connect to programmer TX
6	+3V3	Power Input	+3.3 V Power Input

[2]Note that this interface is internally connected to the pin header's $\overline{\text{BTN}}$. Pay attention to the button switch state when using the programming port.

1.3. Electrical Characteristics

1.3.1. Absolute Maximum Ratings

Operating the device beyond the absolute maximum ratings may cause permanent damage. Long-term operation at absolute maximum conditions may affect device performance and reliability.

Table 3: Absolute Maximum Ratings Table

Parameter	Symbol	Min	Max	Unit	Notes
Ambient Temperature	T_A	-25	85	°C	
Power Supply Voltage	V_{IN}	0	40	V	
Fan Drive Load Current	I_{FAN}	—	600	mA	

1.3.2. Recommended Operating Conditions

Table 4: Recommended Operating Conditions Table

Parameter	Symbol	Min	Max	Unit	Notes
Ambient Temperature	T_A	-25	85	°C	
Power Supply Voltage	V_{IN}	15	36	V	
Fan Drive Output Voltage	V_{FAN}	—	12	V	
Fan Power	$P_{\mathrm{FAN\_MAX}}$	—	6	W	

1.3.3. DC Characteristics

The following parameters are measured at room temperature (25°C) with a 24 V power supply.

Table 5: DC Characteristics Table

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions
Typical Power Consumption	P_{TYP}	—	0.5	—	W	Without fan connected

2. Detailed Description

2.1. Product Overview

The Buce series is an integrated embedded WiFi dimming controller module designed for aquarium lighting and other high-power multi-channel applications. It is capable of outputting 6-channel PWM dimming signals, making it particularly suitable for high-end freshwater[3] (aquatic plant) lighting.

The module is designed around the Espressif ESP32-C3 WiFi MCU and includes peripheral circuits to support a wide input voltage range from 15V to 36V. It integrates a thermal management system based on NTC thermistors, speed-controlled fans, and PID algorithm closed-loop control, fully meeting the needs of high-power LED lighting. The module also includes safety features such as over-temperature protection to safeguard expensive high-end LED beads.

After configuration via a open-source mobile app, the module can autonomously implement functions such as dimming, timed sunrise/sunset, night light(temporary lighting), and automatic on/off. The accompanying mobile application also supports multiple languages.

The module integrates a fan drive circuit, enabling 2-wire fan speed control via voltage regulation, eliminating the need for more expensive 4-wire PWM fans and reducing the final product costs. Additionally, through software configuration, the module supports PWM fan control signals, enhancing design flexibility.

By using a WiFi MCU and integrating essential circuits for aquarium lighting (excluding LED power drivers), the module greatly reduces the difficulty and cost of developing smart WiFi aquarium lights. Users only need to connect an NTC thermistor, fan, and LED power driver to develop a fully functional, sunrise/sunset-enabled high-end aquarium light.

2.2. General Specifications

Table 6: General Specifications Table

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
RF Frequency Range	F	2,412	—	2,484	MHz	—
LED PWM Dimming Channels	D_{PWM}	1	6	6	—	
LED PWM Dimming Frequency	D_{FREQ}	1	19	19	kHz	Software configurable
LED PWM Dimming Level	D_{V}	0	3.1	3.3	V	—

[3] For marine(saltwater) LED requiring more than 6-channel dimming, consider the Colorata (Model BLC10) series 10-channel controller module.

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
PWM Dimming Duty Cycle Steps	D_{DUTY}	—	4,096	—	STEP	—
Supported NTC Nominal Resistance	R_{25}	—	10	—	kΩ	—
Supported NTC β Value	β	—	3950	—	—	—
Supported Fan Rated Voltage	V_{FAN}	—	12	—	V	—
Fan PWM Level	F_{PV}	0	3.1	3.3	V	—
Fan PWM Frequency	F_{FREQ}	0.1	24	40	kHz	Software configurable
Fan Voltage Regulation Range	F_{VR}	3.5	—	12.2	kHz	Software configurable
Current Sense Resistor	R_{SHUNT}	—	0.1	—	Ω	Optional

2.3. Functional Block Diagram

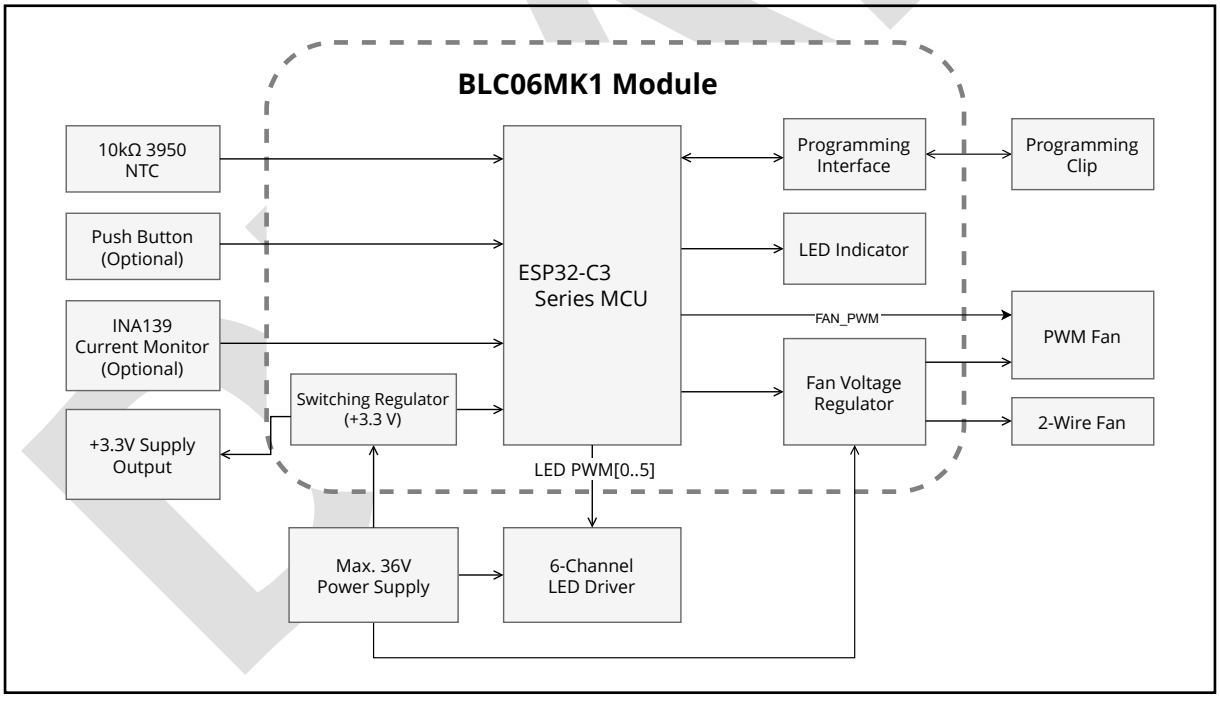


Figure 4: Functional Block Diagram

2.4. Internal Schematic

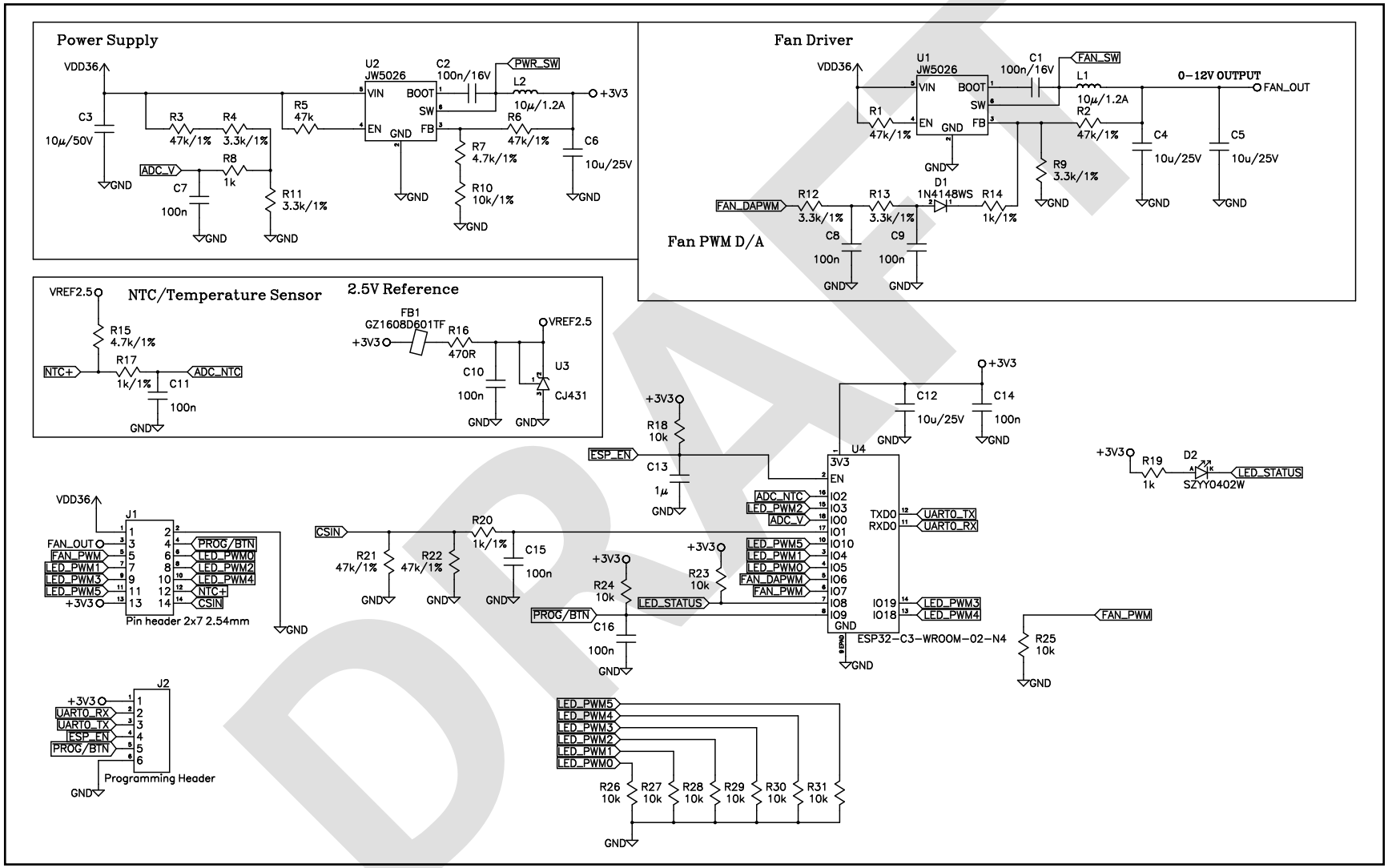


Figure 5: Internal Schematic

2.5. Features Description

2.5.1. RF and Communication

- Communication uses 2.4GHz WiFi with ESPTouch for network configuration
- Local connection via UDP carrying standard CoAP + CBOR protocols
- Device discovery via mDNS/Zeroconf
- Remote server connection via encrypted MQTT[4]
- Network time synchronization via SNTP

2.5.2. Layout

- Compact design dimensions
- Can be integrated into custom PCBs using the open-source schematic
- Reference designs provided[5]

2.5.3. High Integration

- Wide input voltage range: 15V to 36V
- 6-channel independent hardware PWM dimming signal output
- Configurable dimming frequency (default 24 kHz)
- Integrated fan drive circuit, capable of directly driving 12V 2-wire, 3-wire, and 4-wire PWM fans
- Integrated NTC and PID algorithm closed-loop thermal management subsystem
- Automatic over-temperature protection and external INA139 current sensing support

2.5.4. Firmware Features

- Autonomous support for timed on/off, sunrise/sunset, multi-segment dimming, and other high-end aquarium lighting functions
- Night light/temporary lighting mode
- Fully open-source firmware and mobile app
- Cross-platform app supporting Android/iOS/Linux/Windows/MacOS
- Open communication protocol with Python API

For details on firmware and communication protocols, refer to the online documentation[6].

2.6. WiFi Wireless Connection and Protocols

2.6.1. WiFi Configuration

WiFi configuration is used to transmit the SSID and password of the target WiFi hotspot to the module, allowing the device to connect to the network. The module uses Espressif's official ESPTouch SmartConfig method for configuration. This method modulates the SSID and password into the length of WiFi data frames, allowing the module to demodulate and connect to the WiFi hotspot.

[4] Open-source version does not include server-related functionality
[5] Refer to the Section 5 section of this document
[6] docs.borneoiot.com

For details on SmartConfig and ESPTouch, refer to Espressif's official documentation.

If the user's network configuration changes, the module provides three ways to reset the WiFi connection and re-enter the configuration mode:

1. If the final product design includes a press button, the user can hold the button for more than 15 seconds to enter reconfiguration mode.
2. For buttonless designs, after the device is powered on, power it off and then on again within 100 seconds, and repeat this process at least three times. This will clear the existing WiFi connection information in the device and re-enter the waiting for WiFi provisioning mode.
3. The module can also reset WiFi connection information via the mobile app, enabling network switching.

2.6.2. Device Discovery

Using the accompanying mobile app, once the device is configured, it will automatically search for devices via mDNS/Zeroconf. Users can simply click to register the discovered device in the app and control it.

2.6.3. Device Connection and Communication

The mobile app prioritizes reliable local CoAP connections but can also control remote devices via MQTT and backend servers[7].

2.7. PWM Dimming

The module outputs up to six channels of PWM dimming signals, which can be directly provided to LED constant current drive circuits.

The module supports scheduling mode (multi-segment sunrise/sunset simulation), manual mode, night light mode, and more. In scheduling mode, the module autonomously adjusts brightness based on app settings to simulate sunrise and sunset.

Night light mode is used for temporary lighting, where the light will automatically turn off after a set period and return to the previous mode.

2.8. Press Button Functions

The module supports an external press button for powering on the device, toggling temporary night light mode, or using a long press for reconfiguration.

- **Short Press**
  - When the device is powered off, a short click on the button will turn the power on.
  - When the device is powered on and in scheduling mode, pressing the button activates night light mode. The device will temporarily light up for a set duration (default 20 minutes, configurable) before returning to scheduling mode.
  - When the device is already in night light mode, pressing the button immediately returns to scheduling mode.

[7] Open-source version does not include MQTT and backend server functionality

- **Long Press**
  - When powered on, holding the button for more than 15 seconds disconnects and clears WiFi connection information, entering reconfiguration mode.

2.9. Thermal Management

The module includes built-in NTC ADC temperature sampling and a PID closed-loop algorithm for automatic fan control and drive circuit to measure temperature and adjust fan speed.

When the firmware detects temperatures exceeding the software-set threshold, the system can perform an automatic emergency shutdown, extending LED lifespan and improving safety.

2.10. Mobile App

The module comes with an open-source mobile app as the end-user interface. For details, refer to the online documentation: docs.borneoiot.com/mobile-app.

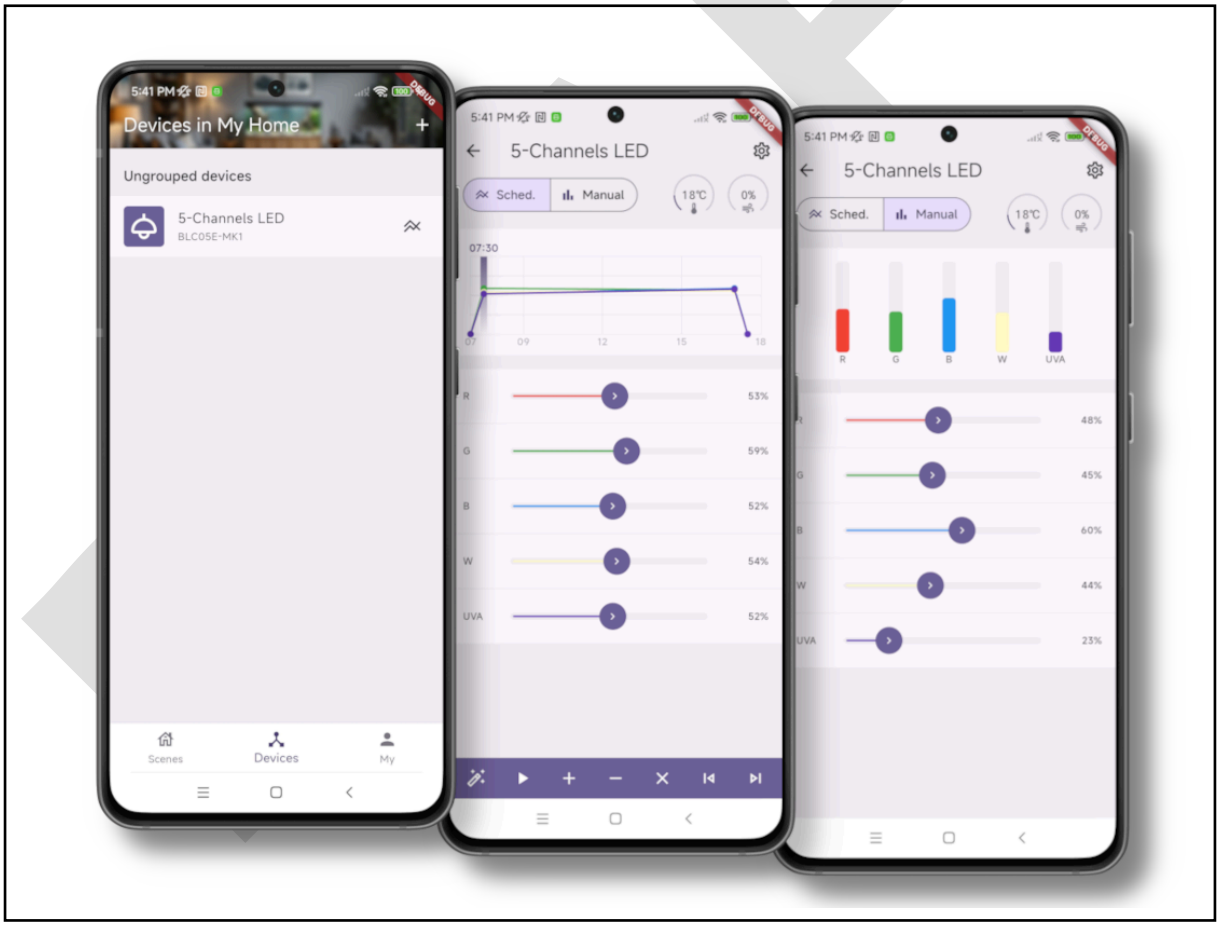


Figure 6: Mobile App Screenshots

3. Applications and Implementation

3.1. Application Information

3.1.1. Onboard Indicator

The module includes an onboard indicator to display important device information.

Table 7: Onboard Indicator States Table

Indicator State	Description
Off	No power, reverse polarity, or module circuit damage
Slow blinking at 1Hz	No network connection. Check the router or reset WiFi information and reconfigure
Fast blinking at 0.2Hz	Device encountered a fatal error, usually indicating hardware failure
Steady on	Connected to WiFi network, device is running normally

3.1.2. Firmware Flashing

The programming port of the module uses a 1.27 mm (50 mil) pitch 6-pin programming clip. The serial port is also used for QA testing during mass production.

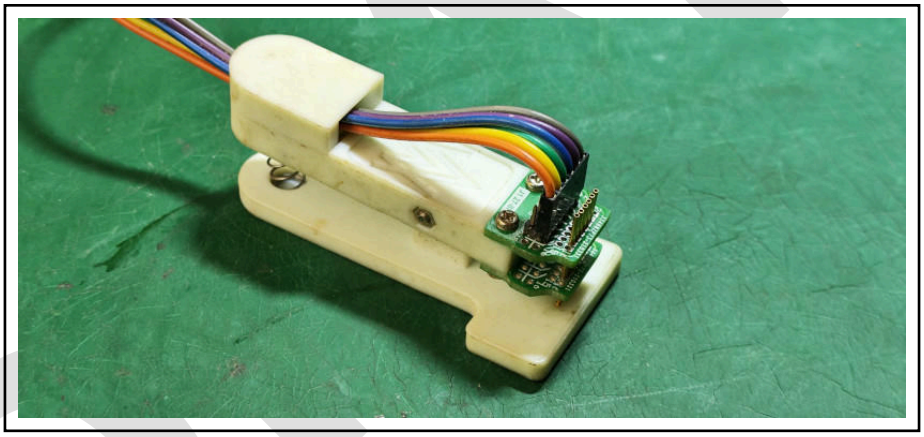


Figure 7: Programming Clip Appearance

> ⚠ **Note**
>
> The programming port's `+3.3 V` input is internally connected to the module's 3.3 V output. When powering the module via the `VIN+` pin, do not connect the programming port's `+3.3 V` to the programmer to prevent current backflow.

3.2. Typical Application

Figure 8 demonstrates a typical 6-channel LED lighting peripheral circuit. The INA139 current monitoring circuit, 74LVC245/74HC245 buffer, push button, and fuse are optional and can be included based on final product requirements.

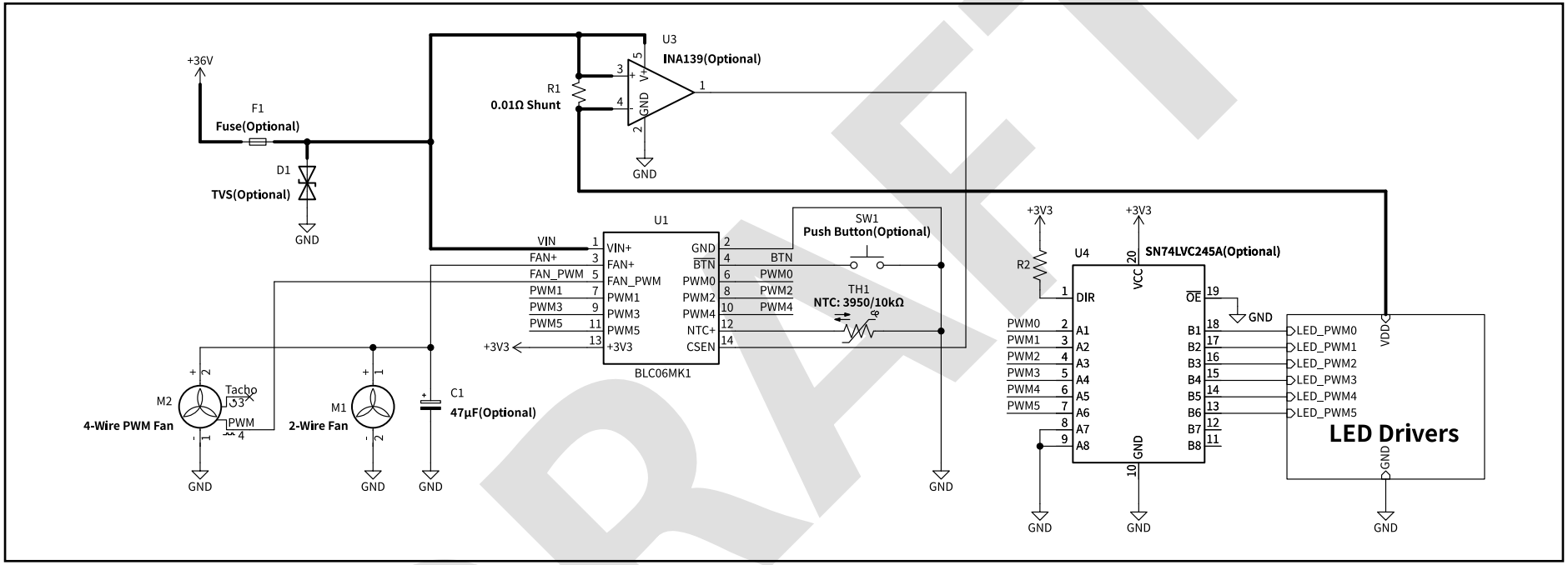


Figure 8: Simplified External Circuit Connection Diagram

Note that Figure 8 is a simplified diagram, omitting decoupling capacitors, INA139 common-mode filtering circuits, etc. Refer to the respective component datasheets for details on using INA139 and 74LVC245.

3.3. Recommended Peripherals

3.3.1. PWM Signal Buffering

If the LED PWM signal line is relatively long, it is recommended to use 74LVC245/74HC245 to buffer the LED PWM signal before the LED driver to enhance the PWM signal quality.

3.3.2. Fan Selection

The module is compatible with both standard two-wire fans and PWM-controlled fans. Any cooling fan with a rated voltage of 12V and a rated power of less than 6W is suitable for use.

For cost reduction purposes, it is recommended to use a two-wire fan.

Note, however, that the module does not support fan speed monitoring.

3.3.3. NTC Selection

This module supports the most commonly used 10 kΩ NTC thermistor with a β value of 3950. For more precise temperature measurement, it is recommended to use a surface-mount NTC thermistor soldered onto the aluminum PCB of the LED chips.

3.4. Peripheral Circuit Design Considerations

- The PWM0 to PWM5 pins are internally pulled down to GND via 10 kΩ resistors; no external pull-down resistors are needed.
- When driving LEDs with constant voltage (**NOT RECOMMENDED**), PWM dimming pins should be connected to the LED MOSFET gate with a series resistor (typical 100Ω) to prevent overshoot.
- A TVS diode is recommended at the power input for circuit protection.
- A 47 µF or larger capacitor (ceramic or electrolytic) is recommended at the fan output to avoid potential fan noise.
- The $\overline{\text{BTN}}$ pin is internally pulled-up and connected to ESP32-C3's `GPIO9` already. If not using a push button, leave it unconnected to avoid boot issues.
- The 6-pin programming port should not be used in user's final product.

4. Mechanical Dimensions and Package Information

4.1. DIP-14 Package

4.1.1. Mechanical Dimensions

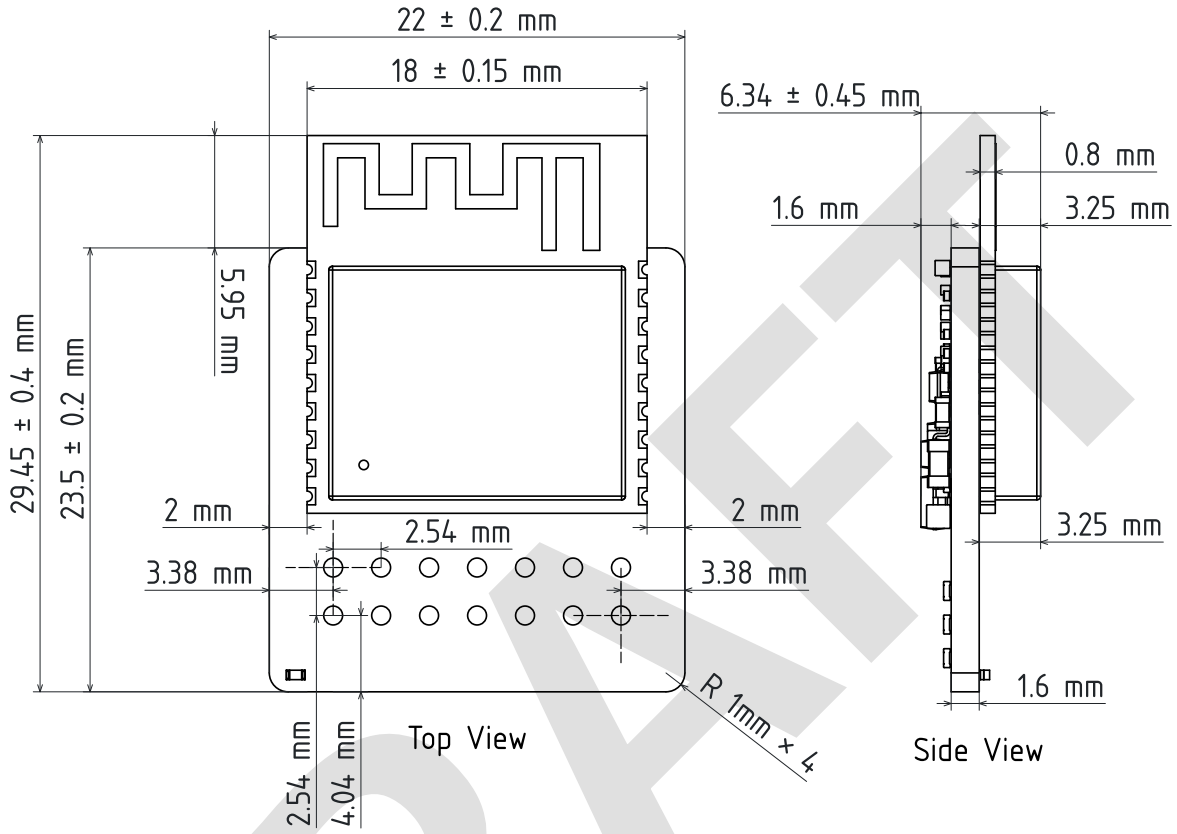


Figure 9: Buce Module DIP-14 Package Mechanical Dimensions

4.1.2. Product Variants

The pin-header version of the Buce module is available in multiple variants, differing only in antenna type and pin-header orientation.

The numbers in the following table are all nominal values in **mm**.

Table 8: Product Variant Mechanical Dimensions

Model	Package	Pin Count	Pin Rows	Pin Pitch	Pin Diamter	Antenna Type
BLC06MK1	14-DIP	14	2	2.54	0.64	PCB
BLC05MK1U	14-DIP	14	2	2.54	0.64	IPX

4.2. PCB Layout Guidelines

4.2.1. Vertical Pin Header Installation

Vertical pin-header modules use standard 2.54 mm JST XH headers, which can be soldered directly into PCB through-holes or mounted via pin-sockets.

4.2.2. Surface-Mount Horizontal Pin Header Installation

For surface-mount horizontal modules, it is recommended to use Samtech SMH-107-02-G-D or compatible 2.54 mm pitch dual-row 14-pin SMD pin sockets.

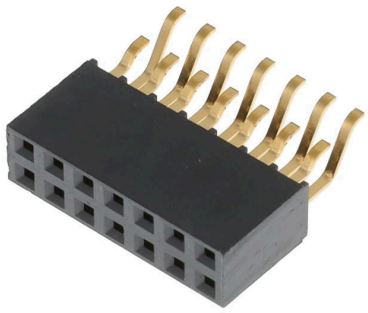


Figure 10: Samtech SMH-107-02-G-D Appearance[8]

4.2.3. PCB Antenna Layout

When using the PCB antenna variant, ensure the antenna is as far as possible from metal components. Avoid traces and copper pours within at least 15 mm around and below the antenna. If possible, leave the area under and around the antenna empty.

[8] Image copyright belongs to DigiKey Corporation, for reference only.

5. Related Resources

- **Official Website**
  www.borneoiot.com
- **Online Documentation**
  docs.borneoiot.com
- **GitHub Open-Source Project**
  github.com/oldrev/borneo
- **Open-Source 6-Channel Aquarium Light Reference Design**
  github.com/oldrev/borneo/tree/master/hw/blb0657f

6. Indexing

6.1. Figures

6.2. Tables

7. Revisions

REV1 - 2025-02-18
Initial version under development.

REV2 - 2025-04-27
Update dimming PWM range and frequency.

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