# BLC05MK3 WiFi 5-Channel LED PWM Controller Module

Features

- Highly integrated 5-channel LED PWM controller based on Espressif ESP32-C3
- 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 4 kHz)
- Built-in NTC support circuit and reference voltage source
- Fan voltage regulation circuit based on PID algorithm, capable of directly driving 12 V fans for speed control
- Supports both 3-wire and 4-wire 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 2×3.5 cm
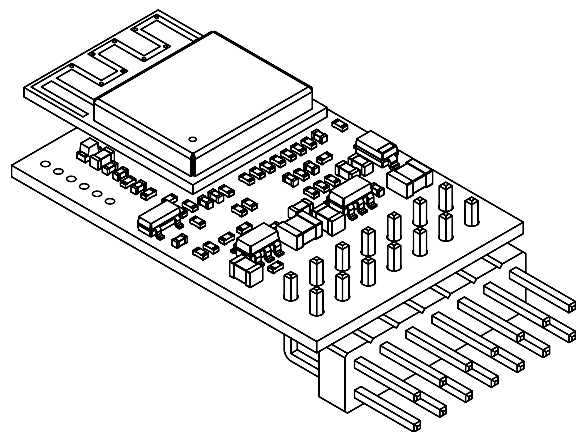- Fully open-sourced
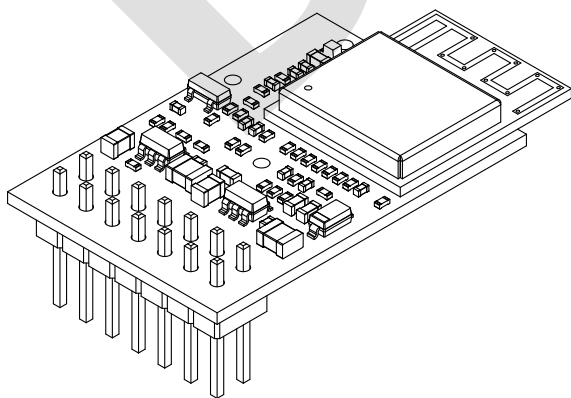
Overview

The BLC05MK3 family is an embedded WiFi dimming controller module designed for aquarium LED and other high-power LED lights, capable of outputting independent 5-channel PWM dimming signals.

After configuration via a cross-platform mobile app, this module can autonomously implement functions such as dimming, timed sunrise/sunset, night light, and automatic on/off.

Includes horizontal pin header models for space-saving horizontal installation.

Applications

- Smart high-power LED aquarium lighting
- Agricultural LED applications
- Beauty and therapy devices
- High-end adjustable lighting or ambient LEDs

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 BLC05MK3 module. Other variant have similar dimensions. Models with the suffix "U" use the ESP32-C3-MINI-U, which comes with an IPX antenna socket instead of a PCB antenna.
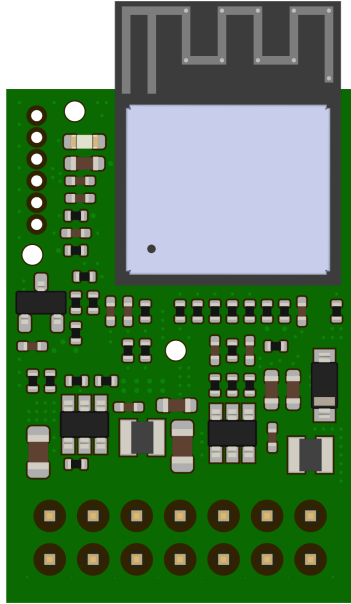
Figure 1: Appearance Diagram
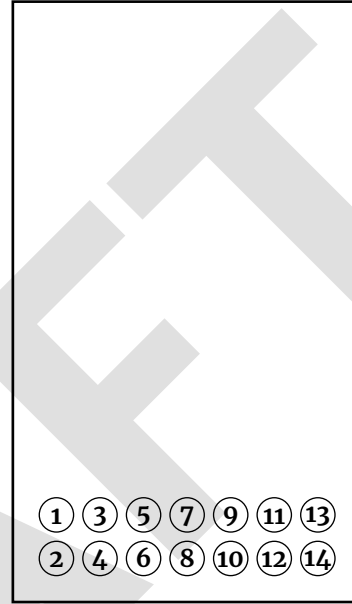
Figure 2: Pinout Diagram

All BLC05MK3 family modules share the same pin definitions. Models with the suffix "H" use a 90° pin header. 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	36 V Main Power Input
2	GND	—	0V, Ground
3	3V3	Power Output	+3.3 V Output
4	$\overline{\text{BTN}}$	Input	Button Input
5	NTC+	Input	3950 10k NTC Input
6	CSEN	Input	INA139 Current Monitor Input
7	STAT	Output	LED Indicator Output
8	PWM0	Output	Channel 0 PWM Signal Output
9	PWM1	Output	Channel 1 PWM Signal Output
10	PWM2	Output	Channel 2 PWM Signal Output
11	PWM3	Output	Channel 3 PWM Signal Output
12	PWM4	Output	Channel 4 PWM Signal Output

Pin #	Name	Type	Description
13	FANOUT	Power Output	12 V Fan Drive Output[1]
14	FANPWM	Output	Speed Control Fan PWM Signal Output

1.2. Programming Port

Figure 3: Programming Port Diagram
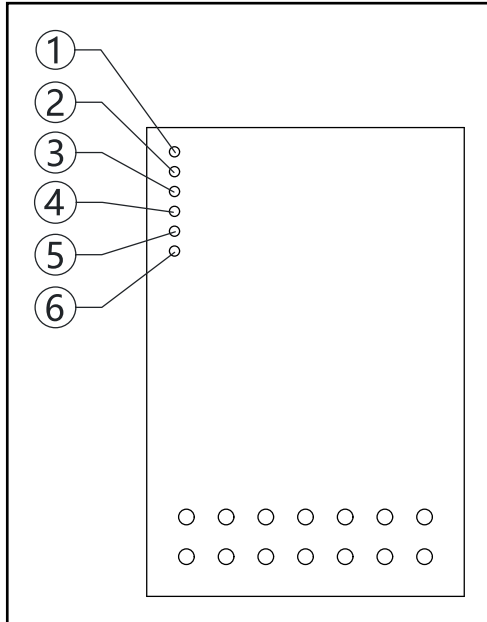
As shown in Figure 3, the programming port is located at the top-left of the module PCB and is used for debugging, firmware flashing, and initial configuration. Its functions and definitions are listed in Table 2.

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	+3V3	Power Input	+3.3 V Power Input
2	UART0_TX	Output	Module UART0 TX, Connect to Programmer RX
3	UART0_RX	Input	Module UART0 RX, Connect to Programmer TX
4	$\overline{\text{EN}}$	Input	Module Reset Interface, Low Level Resets
5	$\overline{\text{PROG}}/\overline{\text{BTN}}$	Input	Low Level Sets Module to Programming Mode, High Level or Floating for Normal Boot[2]
6	GND	—	0 V, Ground

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[1] When using two-wire fan mode, this voltage varies from 5 V to 12 V for speed control. When using PWM fan mode, it is fixed at 12 V.

[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}	—	700	mA	

⚡ **Warning**

Ensure the power supply voltage is normal, properly grounded, and the polarity is correct before connecting the power. Otherwise, it may cause device damage or personal injury.

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}	5	12.5	V	
Fan Power	P_{FAN_MAX}	—	5	W	

1.3.3. DC Characteristics

The following parameters are measured at room temperature (25°C) with a 24V 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 BLC05MK3 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 5-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. Customers 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	—
PWM Dimming Channels	D_{PWM}	1	5	5	—	Software configurable
PWM Dimming Frequency	D_{FREQ}	0	4,096	8,192	Hz	Software configurable
PWM Dimming Level	D_{V}	0	3.2	3.3	V	—

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[3]For marine(saltwater) LED requiring more than 5-channel dimming, consider the BLC10E 10-channel module from the same family.

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
PWM Dimming Duty Cycle	D_{DUTY}	0	—	100	%	—
PWM Dimming Duty Cycle Resolution	D_{DR}	—	1	—	%	—
Supported NTC Nominal Resistance	R_{25}	—	10k	—	Ω	—
Supported NTC β Value	β	—	3950	—	—	—
Supported Fan Rated Voltage	V_{FAN}	—	12	—	V	—
Fan PWM Level	D_V	0	3.2	3.3	V	—
Current Sense Resistor	R_{SHUNT}	—	0.1	—	Ω	Optional

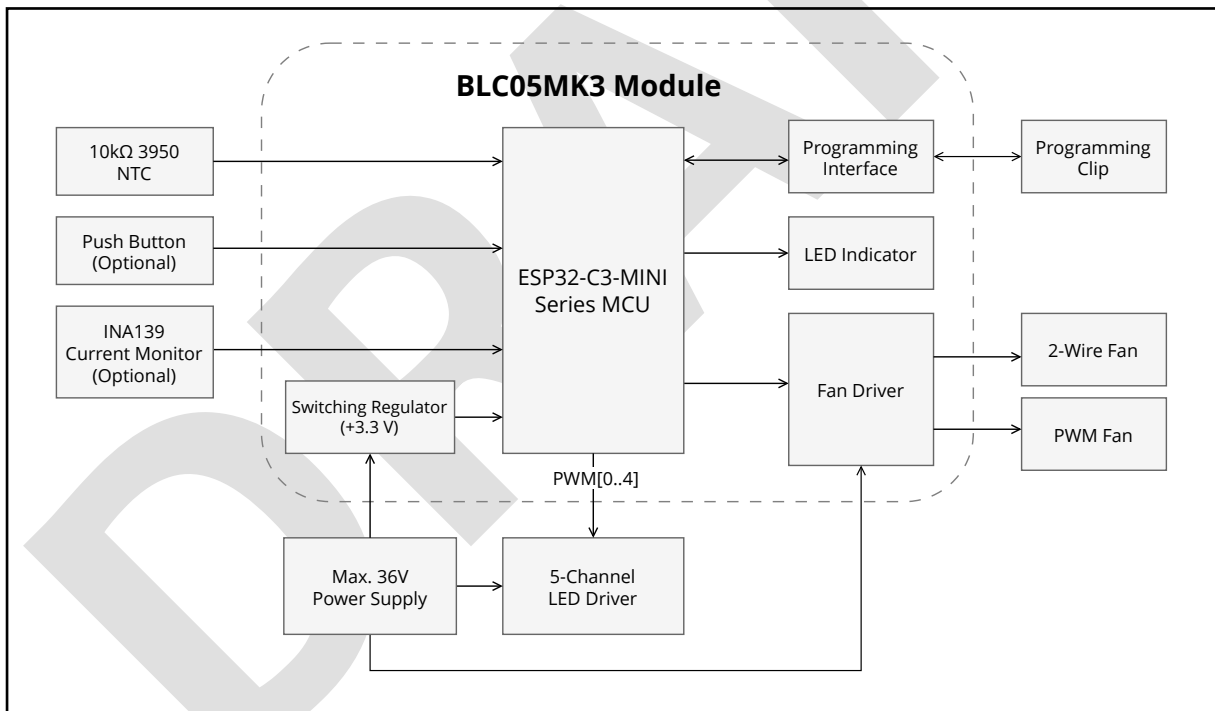## 2.3. Functional Block Diagram

Figure 4: Functional Block Diagram
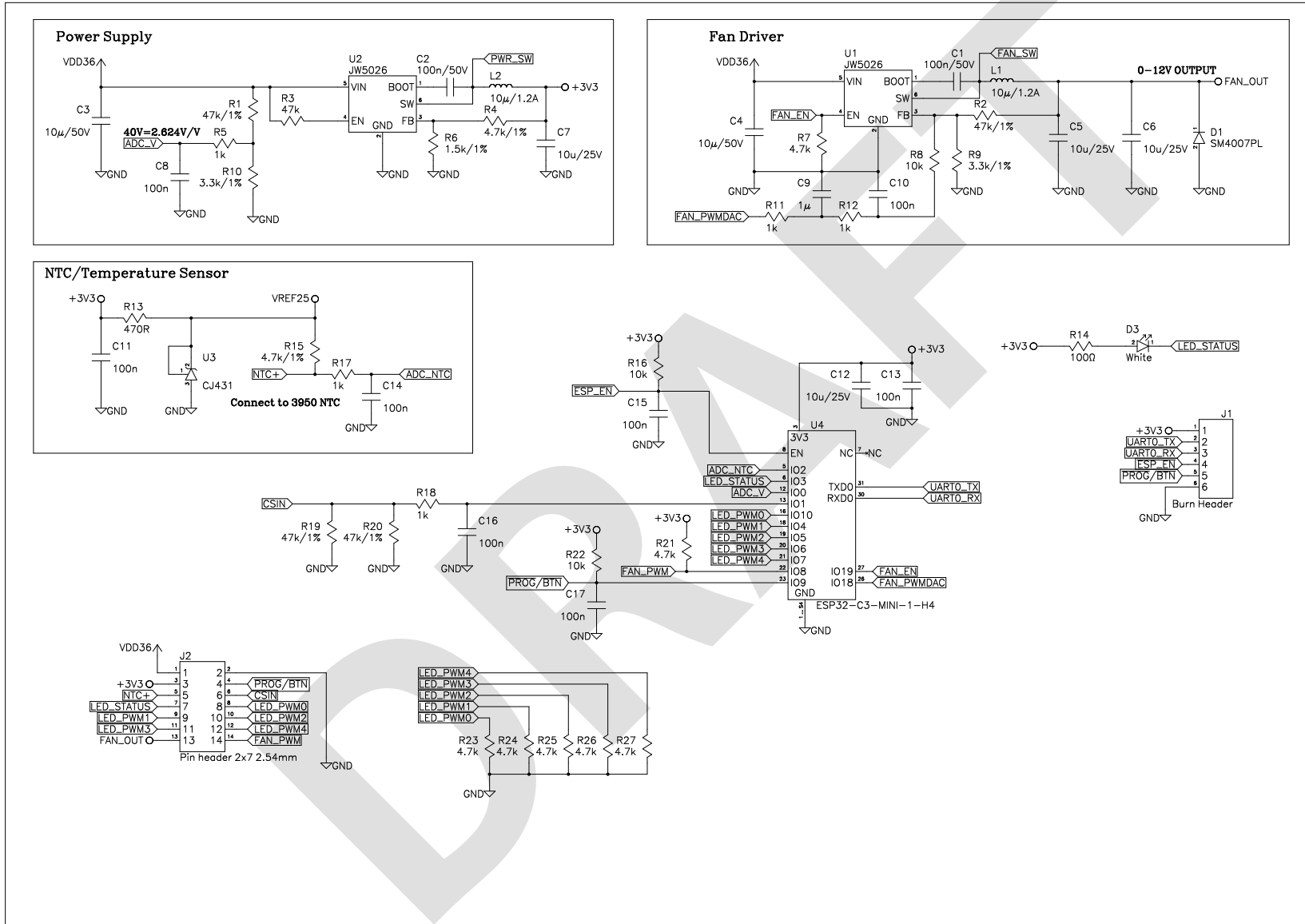
2.4. Internal Schematic

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
· 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
· 5-channel independent hardware PWM dimming signal output
· Configurable dimming frequency (default 4 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 hotspot.

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[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 information 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 night light mode button, the user can hold the button for more than 15 seconds to enter reconfiguration mode.
2. For buttonless designs, repeatedly power cycling the device 5 times will trigger reconfiguration 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 5 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. Night Light Mode Button

The module includes an external night light button for toggling temporary night light mode or long-press for reconfiguration.

· Short press: 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.
· Short press: When the device is already in night light mode, pressing the button immediately returns to scheduling mode.

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

- Long press for more than 15 seconds: 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.
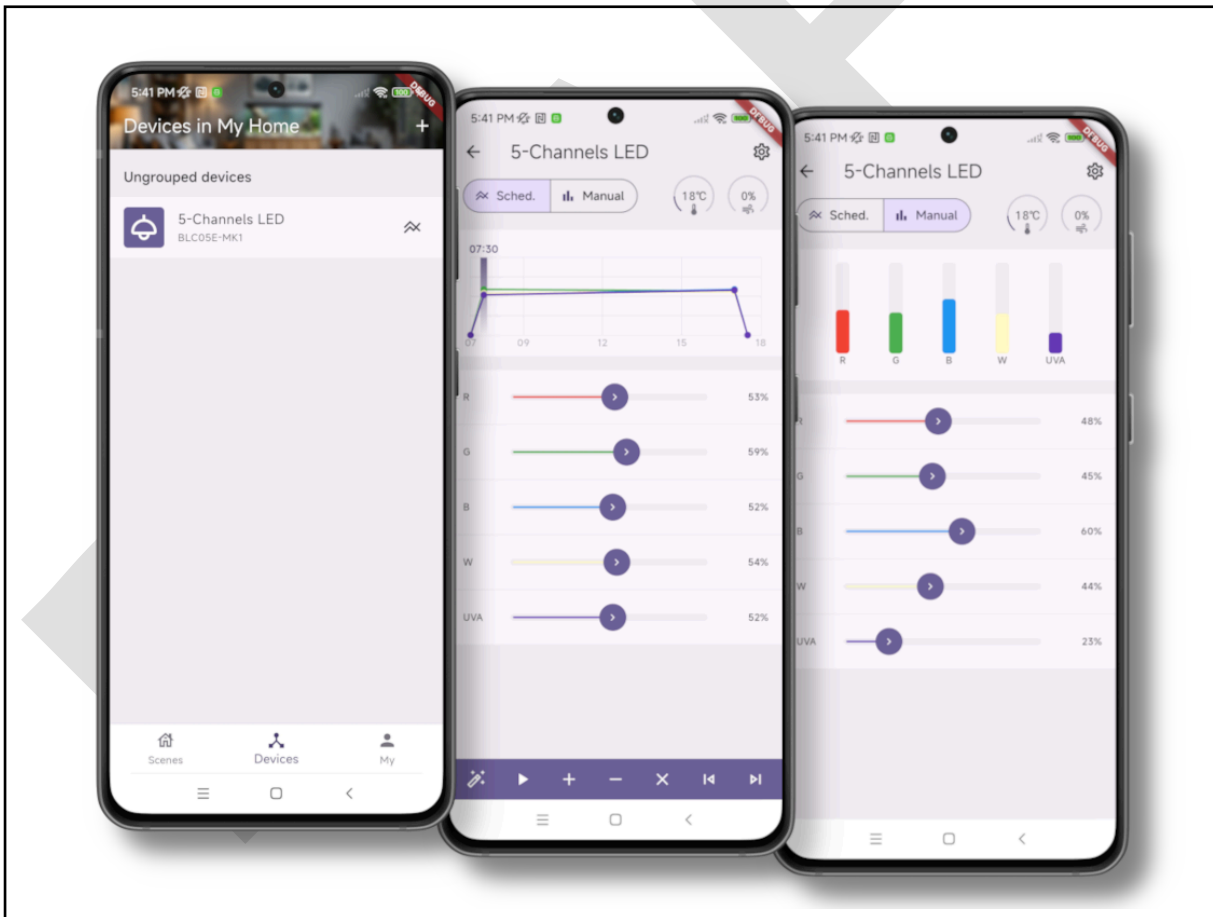

Figure 6: Mobile App Illustration

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	Device normal, 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 running normally

3.1.2. Firmware Flashing

The module's programming port uses a 1.27 mm pitch 6-pin programming clip. The serial port is also used for QA testing during mass production.
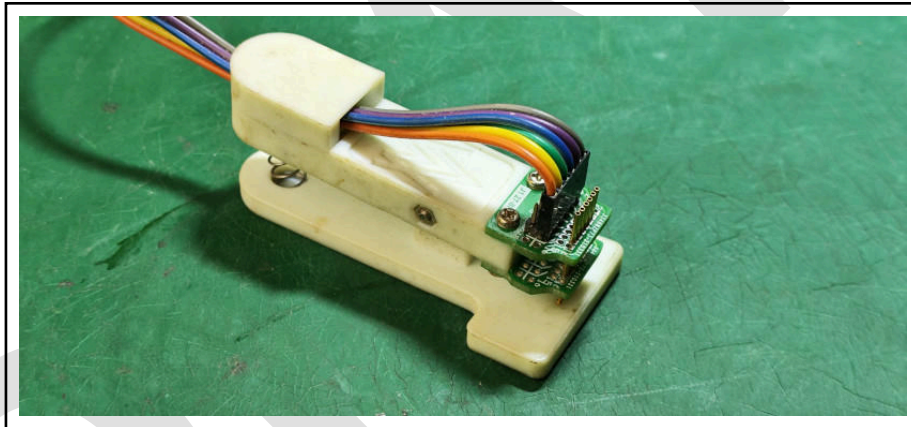

Figure 7: Programming Clip Appearance

> ⚠ **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 5-channel LED lighting peripheral circuit. The INA139 current monitoring circuit, 74HC245 buffer, push button, and fuse are optional and can be included based on final product requirements.
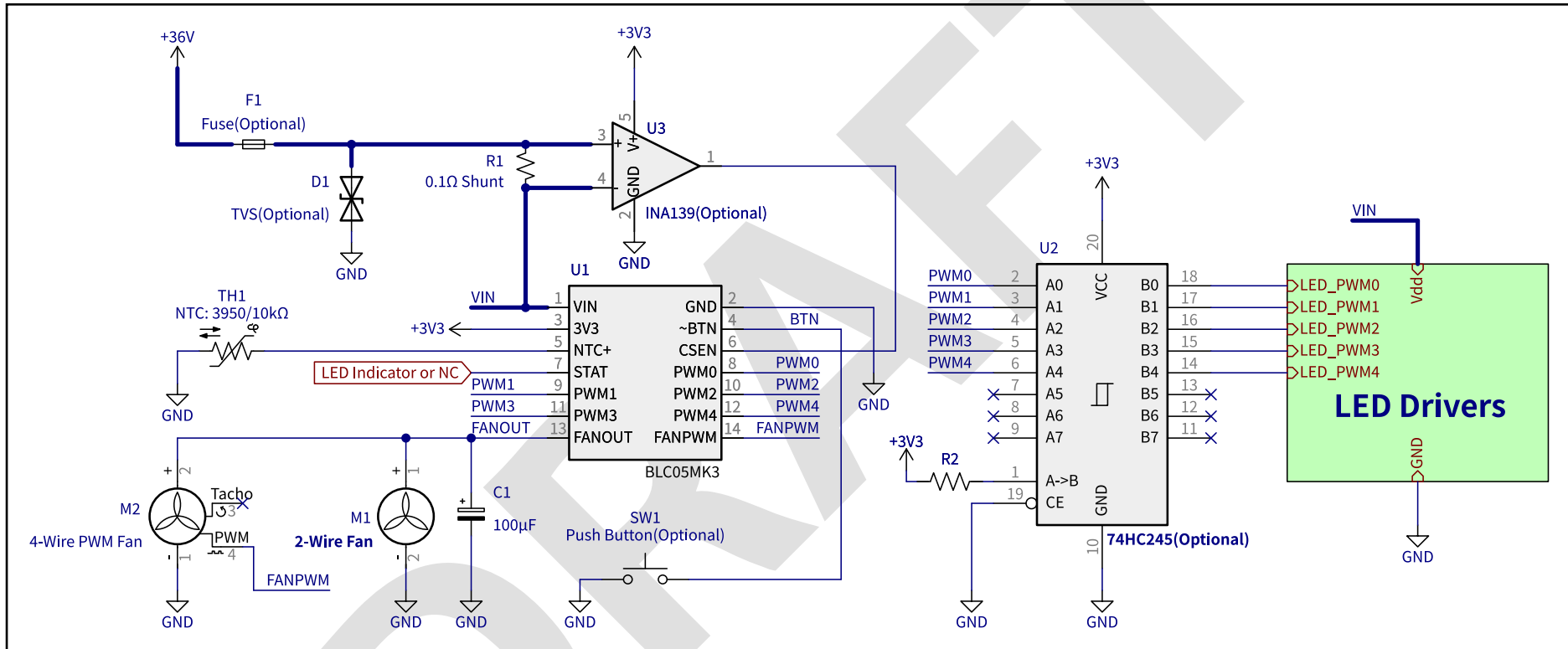

Figure 8: Simplified External Circuit Connection Diagram

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 74HC245.

3.3. Recommended Peripherals

3.3.1. PWM Signal Buffering

If PCB space allows, PWM0 to PWM4 should be buffered via 74HC245 before connecting to the LED power driver.

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 5W 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 a 10kΩ 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 LEDs.

3.4. Peripheral Circuit Design Considerations

- The PWM0 to PWM4 pins are internally pulled down to GND via 4.7kΩ 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 (10Ω to 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 the final product.

4. Mechanical Dimensions and Package Information

4.1. DIP-14 Package

4.1.1. Mechanical Dimensions

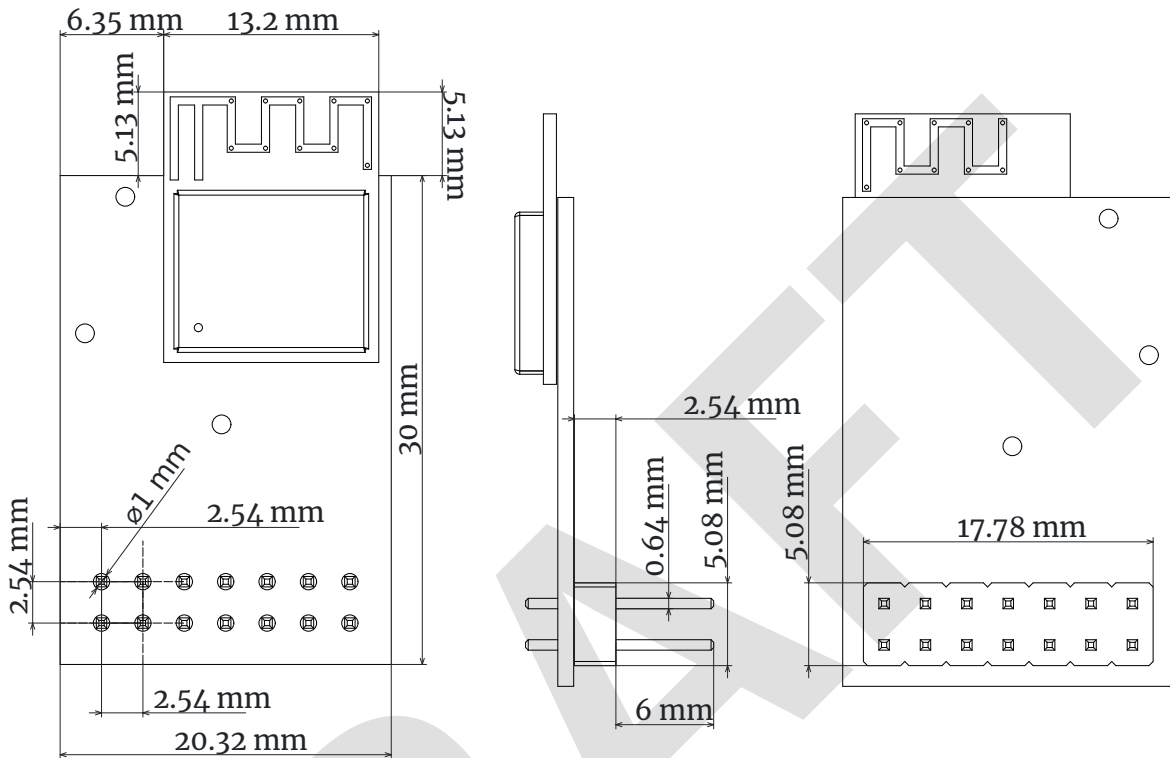Figure 9: BLC05MK3 Module DIP-14 Package Mechanical Dimensions

4.1.2. Product Variants

The pin-header version of the BLC05MK3 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	Pin Orientation	Antenna Type
BLC05MK3	14-DIP	14	2	2.54	0.64	Vertical	PCB
BLC05MK3U	14-DIP	14	2	2.54	0.64	Vertical	IPX
BLC05MK3-H	14-DIP	14	2	2.54	0.64	90° Angle	PCB
BLC05MK3U-H	14-DIP	14	2	2.54	0.64	90° Angle	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.
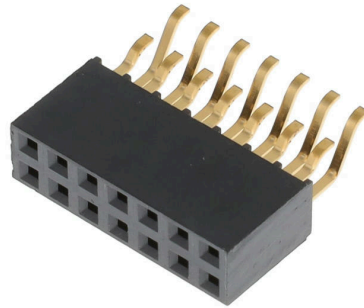
Figure 10: Samtech SMH-107-02-G-D Appearance[8]

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.

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5. Related Resources

· **Official Website**
  www.borneoiot.com
· **Online Documentation**
  docs.borneoiot.com
· **GitHub Open-Source Project**
  github.com/oldrev/borneo
· **Open-Source 5-Channel Aquarium Light Reference Design**
  github.com/oldrev/borneo/tree/master/hw/blb08103

6. Indexing

6.1. Figures

6.2. Tables

7. Revisions

REV1 – 2024/11/15

Initial version under development.

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