BLC06E: 6-Channel Embedded LED PWM Controller

Features

- **Powerful Dimming Features:**
  - 6 × LED PWM hardware channels
  - Output frequency up to 19 kHz
  - 4096-level PWM duty cycle, achieving smooth gradient effects
  - Uses phase-shifted PWM output, greatly reducing peak current at non-full load, reducing power noise and extending lifespan
  - Advanced dimming features:
    - Multi-segment programmable dimming
    - Astronomical algorithm-based sunrise/sunset simulation
    - Temporary lighting, group control, etc.
- **Highly Integrated Hardware:**
  - Size only 20 × 25 mm
  - 20-pin board-to-board connector, 0.8 mm pitch
  - Onboard regulator, up to 36 V
  - Built-in fan drive circuit:
    - Can directly drive 12 V two-wire cooling fans through voltage speed control
    - Supports standard 25 kHz PWM fans
  - Thermistor support circuit
  - Power supply voltage monitoring circuit
  - INA138/INA139 support circuit for collecting LED circuit and performing overcurrent/overpower protection
  - Precision reference voltage source
  - Addressable full-color LED indicator; supports external expansion
  - User button support circuit
- **Built-in Safety:**
  - Supports configurable overcurrent, overtemperature protection
  - Adaptive cooling fan control based on PID algorithm
- Provides a free mobile app
- Provides tools for full feature customization

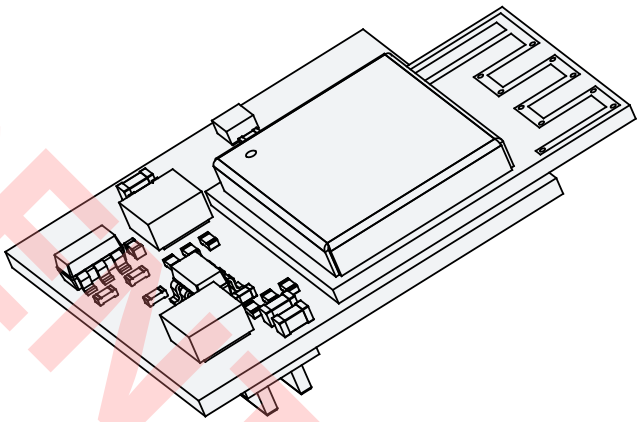
Overview

The BLC06E is an embedded smart 6-channel LED controller designed for professional freshwater and reef light manufacturers. It integrates all the complex and precise circuitry into a coin-sized package, is driven by our in-house firmware platform, and is controlled by the Borneo-IoT App.

Using the BLC06E eliminates the time and cost of firmware and app development, significantly accelerating time-to-market.

Applications

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



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1. Hardware Specifications

1.1. Pin Definition and Functions

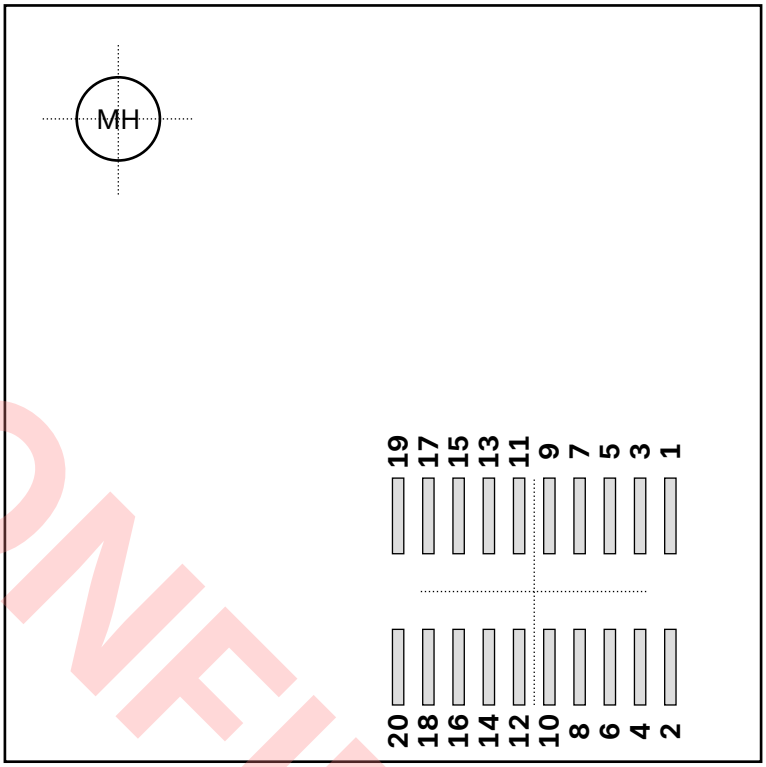


Figure 1: Pinout Diagram (Top View)

All BLC06E family modules share the same pin definitions. The pin order refers to Figure 1, and the functions refer to Table 1.

Table 1: Pinout Table

Pin #	Name	Type	Description
1, 19, MH[1]	GND	—	Ground, 0 V
2	+3V3	Power Output	+3.3 V output
3	$\overline{\text{BTN}}$	Input	Button input
4	U0RX	Input	UART-0 receive line
5	STA_EXT	Output	External addressable LED data port
6	U0TX	Output	UART-0 transmit line
7	PWM0	Output	Channel 0 PWM Signal Output
8	$\overline{\text{RST}}$	Input	MCU reset line
9	PWM1	Output	Channel 1 PWM signal output
10	CSIN	Input	INA138/INA139 current monitor input
11	PWM2	Output	Channel 2 PWM signal output
12	NTC+	Input	3950 10 kΩ NTC input
13	PWM3	Output	Channel 3 PWM signal output
14	FPWM	Output	Fan PWM signal output for speed control
15	PWM4	Output	Channel 4 PWM signal output
16, 18	FAN+	Power Output	+12 V Fan drive output[2]
17	PWM5	Output	Channel 5 PWM signal output
20	VIN+	Power Input	5 - 36 V Main Power Input[3]

[1]Mounting hole.
[2]When using two-wire fan mode, this voltage varies from 3.5 V to 12.5 V for speed control. When using PWM fan mode, it is fixed at 12 V.
[3]When the input voltage is below 15 V, the onboard cooling fan voltage regulator will not function properly, but other functions remain unaffected.

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1.2. Programming Port

The pins U0RX, U0TX, $\overline{\text{RST}}$, and $\overline{\text{BTN}}$ are the programming ports, used for initial firmware burning and factory configuration. Except for $\overline{\text{BTN}}$ which is multiplexed as a user button function, the other pins should remain unconnected in the final product.

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 2: Absolute Maximum Ratings Table

Parameter	Symbol	Min	Max	Unit	Notes
Ambient Temperature	T_A	−25	105	°C	
Power Supply Voltage	V_{IN}	—	40	V	
Fan Drive Load Current	I_{FAN}	—	600	mA	

1.3.2. Recommended Operating Conditions

Table 3: 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	$P_{\text{FAN_MAX}}$	—	6	W	

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1.3.3. DC Characteristics

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

Table 4: DC Characteristics Table

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions
Typical Power Consumption	P_{TYP}	—	0.4	—	W	Wi-Fi connected

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2. Detailed Description

2.1. Product Overview

The BLC06E series is an integrated embedded Wi-Fi 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[4] (aquatic plant) lighting.

The module is designed around the Espressif ESP32-C3 Wi-Fi 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 our free 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 Wi-Fi MCU and integrating essential circuits for aquarium lighting (excluding LED power drivers), the module greatly reduces the difficulty and cost of developing smart Wi-Fi 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 5: 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}	0.5	—	19	kHz	Software configurable
LED PWM Dimming Level	D_{V}	0	3.1	3.3	V	—
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}	—	25	—	kHz	—
Fan Voltage Regulation Range	F_{VR}	0	—	12.5	V	Software configurable
Current Sense Resistor	R_{SHUNT}	10	—	—	mΩ	INA139
		50	—	—	mΩ	INA138

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

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2.3. Functional Block Diagram

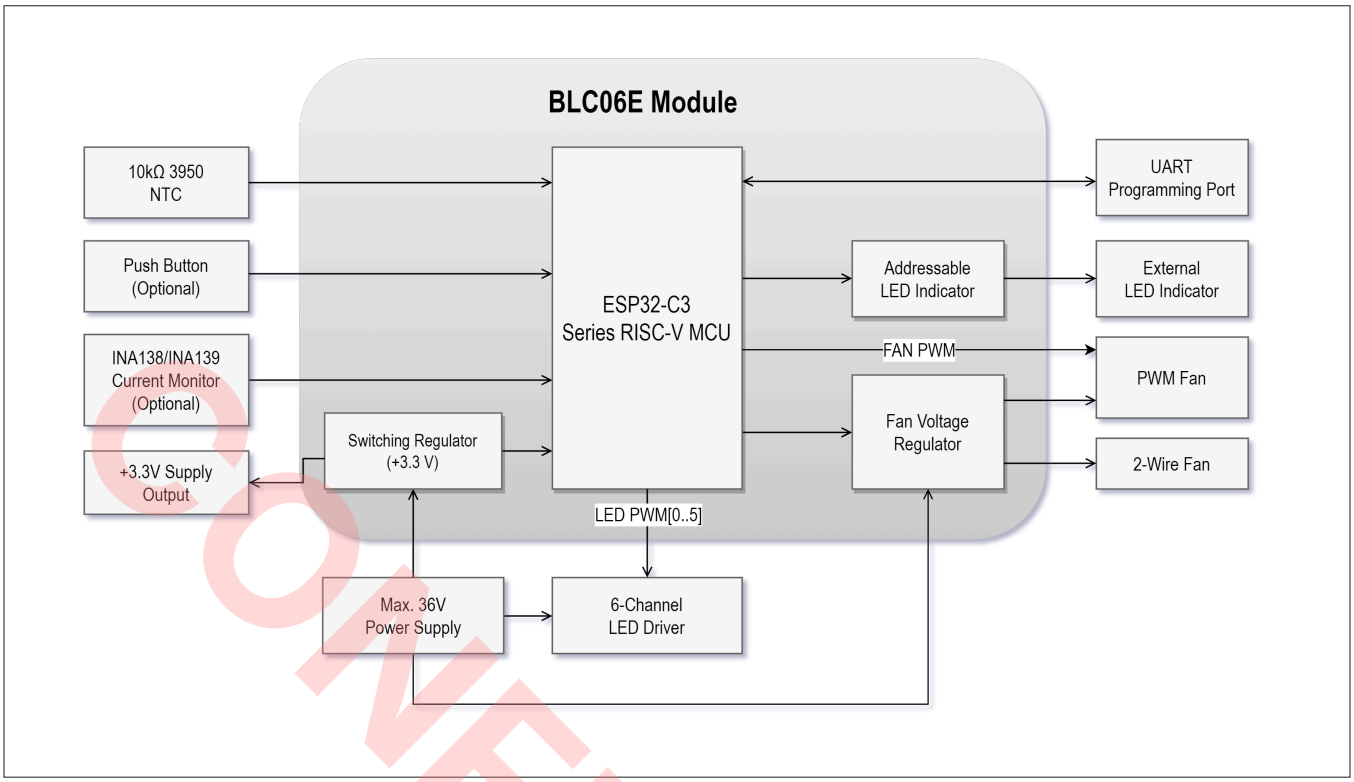


Figure 2: Functional Block Diagram

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2.4. Features Description

2.4.1. RF and Communication

- Communication uses 2.4GHz Wi-Fi 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
- Network time synchronization via SNTP

2.4.2. Layout

- Compact design dimensions
- Reference designs provided[5]

2.4.3. High Integration

- Wide input voltage range: 15V to 36V
- 6-channel independent hardware PWM dimming signal output
- Configurable dimming frequency (up to 19 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

2.4.4. 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].

2.5. Wi-Fi Wireless Connection and Protocols

2.5.1. Wi-Fi Provisioning

Wi-Fi provisioning is used to transmit the SSID and password of the target Wi-Fi 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 Wi-Fi data frames, allowing the module to decode and connect to the Wi-Fi hotspot.

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 Wi-Fi 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 Wi-Fi connection information in the device and re-enter the waiting for Wi-Fi provisioning mode.
3. The module can also reset Wi-Fi connection information via the mobile app, enabling network switching.

2.5.2. 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.

2.5.3. Device Connection and Communication

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

2.6. PWM Dimming

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

[5] Refer to the Section 7 section of this document
[6] docs.borneoiot.com
[7] Open-source version does not include MQTT and backend server functionality

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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.

2.7. Push 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.

2.8. Thermal Management

The module includes an NTC-based temperature sensing ADC and a PID closed-loop algorithm that automatically controls the cooling fan.

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

2.9. Mobile App

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

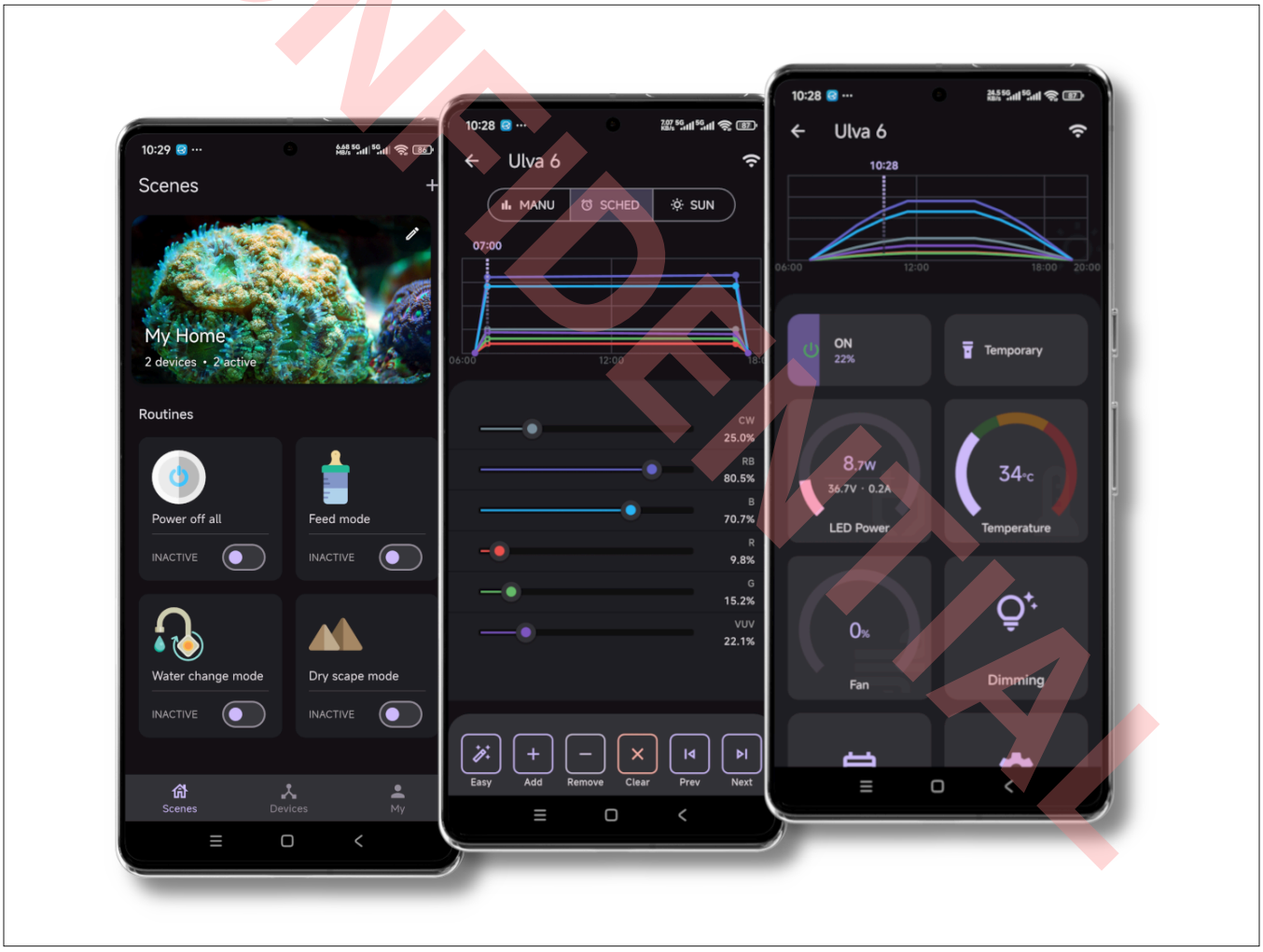


Figure 3: Mobile App Screenshots

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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 6: Onboard Indicator States Table

Color	Indicator State	Description
N/A	Off	No power, reverse polarity, or module circuit damage
Red	Fast blinking at 5 Hz	Device encountered a fatal error, usually indicating hardware failure
Yellow	Slow blinking at 1 Hz	No network connection. Check the router or reset Wi-Fi information and reconfigure
Pink	Steady on	The device is in factory settings mode
White	Steady on	Connected to Wi-Fi network, device is running normally

3.1.2. User Button

The user button is internally connected to the ESP32-C3 MCU's GPIO9 in the BLC06E module and is pulled up to the internal 3.3 V supply through a 10 kΩ resistor. When pressed, it will pull GPIO9 low to GND. Refer to Table 7 for the function of this pin.

Table 7: User Button Usage

Operation	Description
Short press (short time low)	Turn on or off temporary lighting mode
Long press (low for about 10 seconds)	Clear Wi-Fi information, device enters Wi-Fi provisioning mode
First pull $\overline{\text{BTN}}$ low, then pull $\overline{\text{RST}}$ low	Device enters firmware flashing mode[8]

[8] Only for development versions, release versions cannot enter flashing mode.

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3.2. Typical Application

Figure 4 demonstrates a typical 6-channel LED lighting peripheral circuit. The INA139 current monitoring circuit, TH1 NTC, cooling fan, push button, and external indicator SK6805 are optional and can be included based on final product requirements.

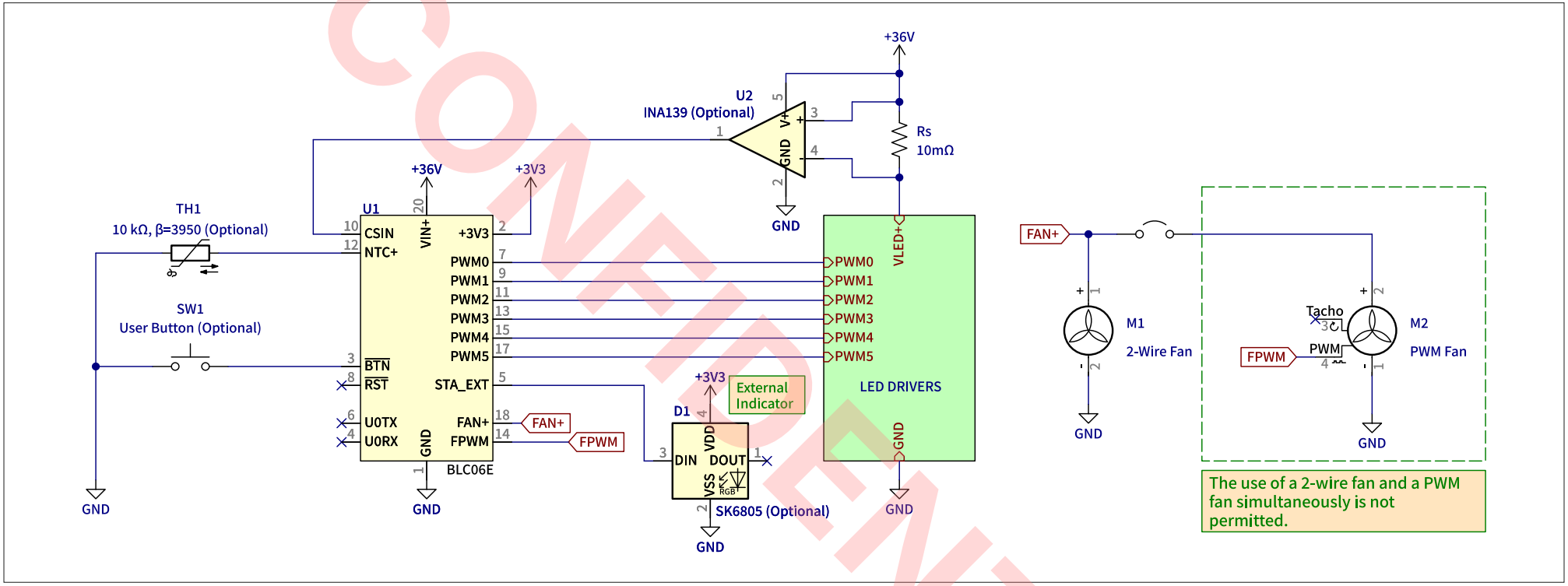


Figure 4: Simplified External Circuit Connection Diagram

Note that Figure 4 is a simplified diagram, omitting decoupling capacitors, INA139 common-mode filtering circuits, etc. Refer to the respective component datasheets for details on using INA139/INA138 and SK6805.

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3.3. LED Driver Selection and Design Considerations

3.3.1. Constant Current Drivers

Constant current drivers are suitable for scenarios where the number of LEDs varies significantly between channels, leading to large voltage drop differences, or where LED power is high and efficiency needs to be ensured. Constant current drivers typically have higher cost and larger size but offer higher efficiency.

- Precise current control prevents LED damage.
- Suitable for series LED strings.
- Higher power efficiency.

3.3.2. Constant Voltage Drivers

Constant voltage drivers are suitable for scenarios where voltage drops between channels are small or power is low. They have smaller size, lower cost, but lower efficiency.

- Flexibility for parallel LED connections.
- Cost-effective for low-power applications.
- Easier to source and integrate.

A simple low-side constant voltage driver is shown in Figure 5, where R_{CL} is used to limit the current through the LED.

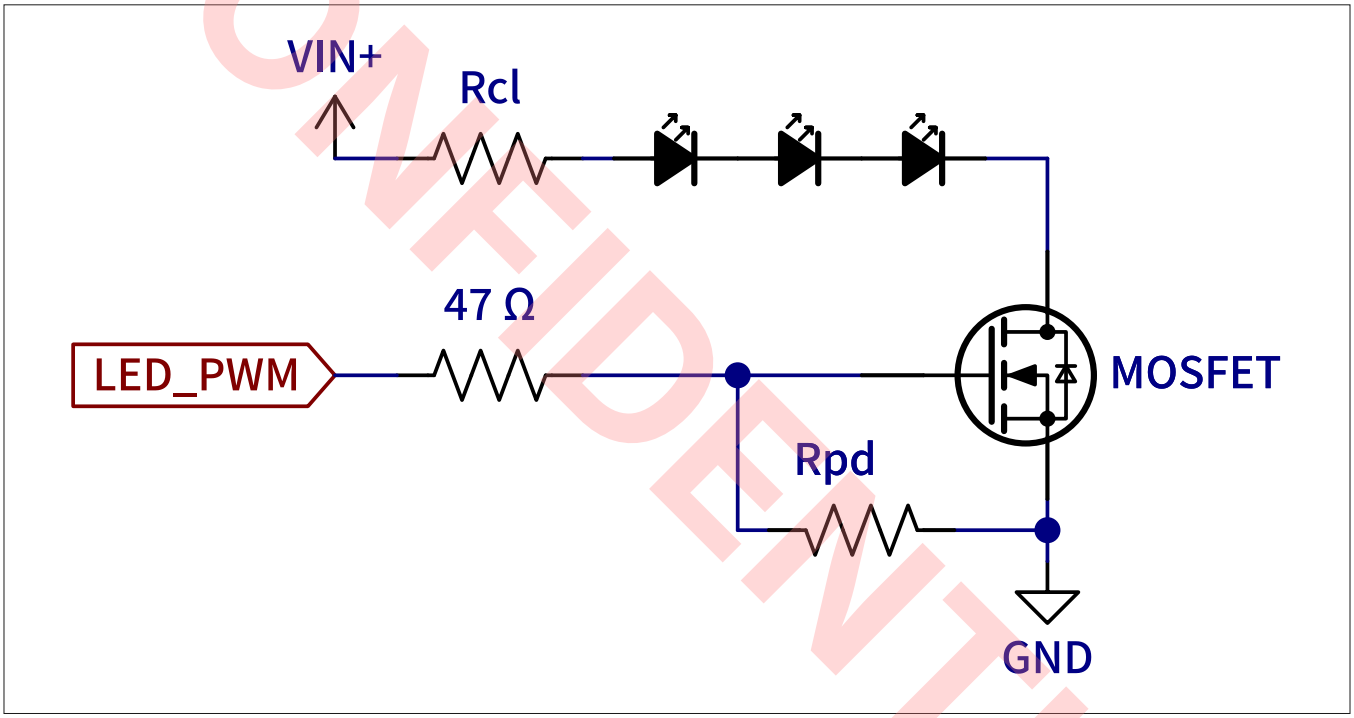


Figure 5: Low-side Constant Voltage MOSFET Driver

For multiple LEDs in series, the current-limiting resistor can be calculated as follows:

$$R_{\mathrm{CL}} = \frac{V_{\mathrm{IN}} - N \cdot V_{\mathrm{F}} - I_{\mathrm{LED}} \cdot R_{\mathrm{DS}}}{I_{\mathrm{LED}}}$$

Where:

- V_{IN} is the supply voltage
- N is the number of LEDs in series
- V_{F} is the forward voltage of each LED
- I_{LED} is the desired LED current
- R_{DS} is the on-resistance of the MOSFET

Note

When driving LEDs with constant voltage, PWM dimming pins should be connected to the LED MOSFET gate with a series resistor to prevent overshoot.

Select MOSFETs with low gate capacitance to improve efficiency.

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3.4. Recommended Peripherals

3.4.1. PWM Signal Buffering

For cases where PCB space and cost allow, it is recommended to use 74LVC245/74HC245 to buffer the LED PWM signal before the LED driver to enhance the PWM signal quality.

3.4.2. Peripheral Current Monitoring Device Selection

Current monitoring devices can use TI INA138 or INA139. The BLC06E module has built-in support circuits. They have the same pin definitions but different gain coefficients, so please refer to the table below for current sense resistor selection.

Model	Relative Gain	Shunt
INA139	1.0	10 mΩ
INA138	0.2	50 mΩ

3.4.3. 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.

3.4.4. 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.

3.4.5. LED Indicator Selection

The onboard indicator of the BLC06E is an addressable full-color LED driven by the SK6805 chip, and the `DOUT` of this chip is led out as the `STA_EXT` pin. It supports directly connecting the `STA_EXT` pin to the `DIN` of an external SK6805 or compatible LED indicator to use both the onboard and external LED indicators simultaneously, providing users with maximum PCB layout flexibility.

> **Note**
>
> Note that the firmware currently limits support to only one external indicator. If users have specific needs to use this indicator for other purposes, this limitation may be modified in the future.

For more information, please refer to the SK6805 chip's datasheet and documentation.

3.5. 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.
- 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 `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 programming pins `U0TX`, `U0RX` and `RST` should not be used in the user's final product.

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4. Mechanical Dimensions and Package Information

4.1. 20-Pin Board-to-board Package

4.1.1. Mechanical Dimensions

The mechanical dimensions of the BLC06E module are shown in the figure below:

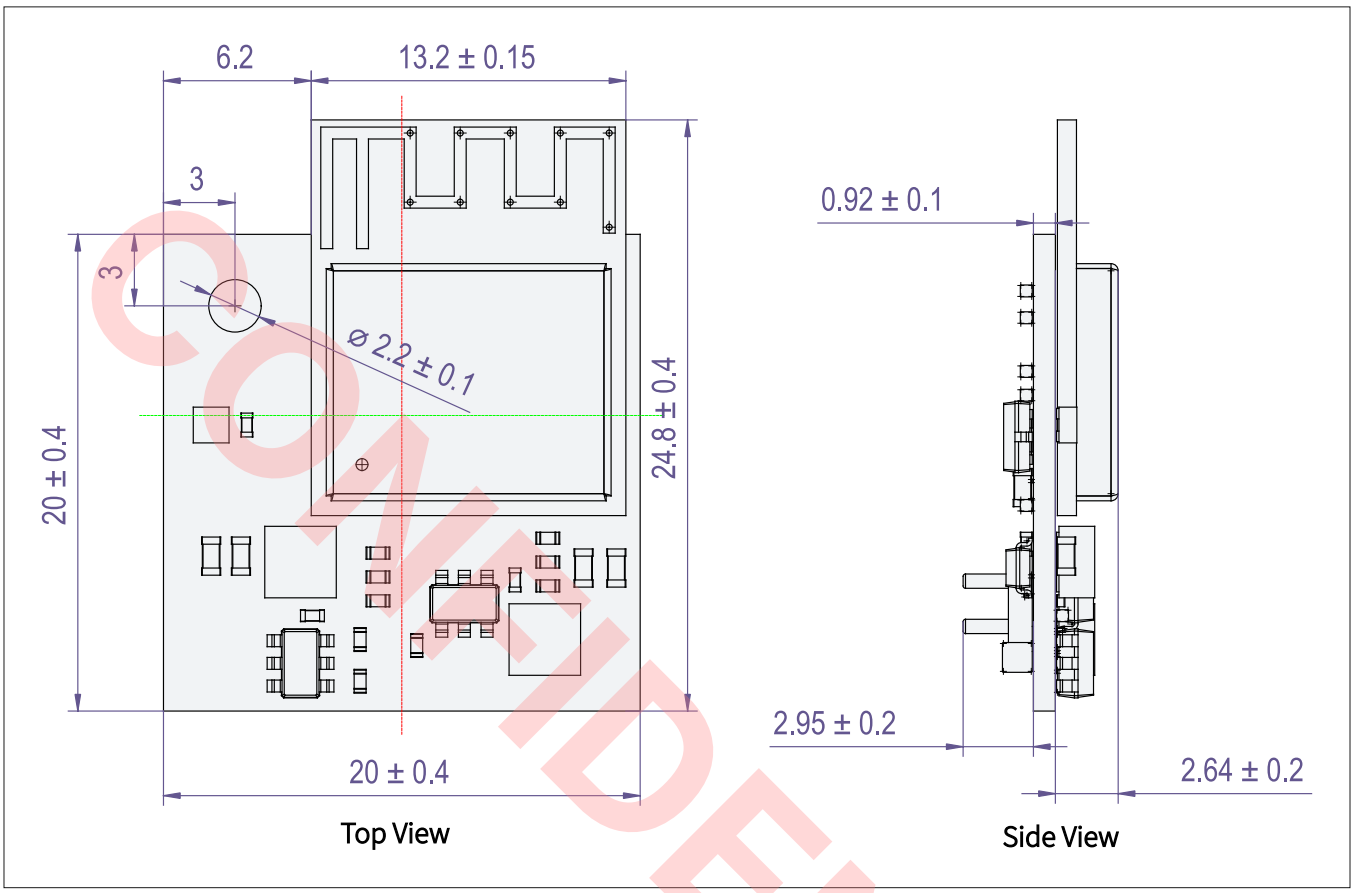


Figure 6: BLC06E Package Mechanical Dimensions (Unit: mm)

4.2. Connectors

The BLC06E uses a 20-pin, dual-row, 0.8 mm pitch male BTB (board-to-board) connector to connect to the user's motherboard, and is secured using SMT standoffs or copper pillars.

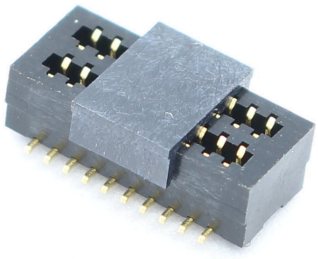


Figure 7: Female BTB Connector Appearance

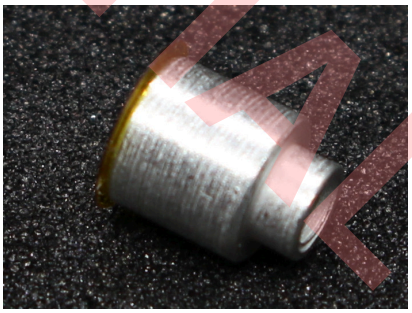


Figure 8: SMT Standoff Appearance

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4.2.1. Board-to-Board Connector

The onboard male BTB connector dimensions are shown in the Figure 9.

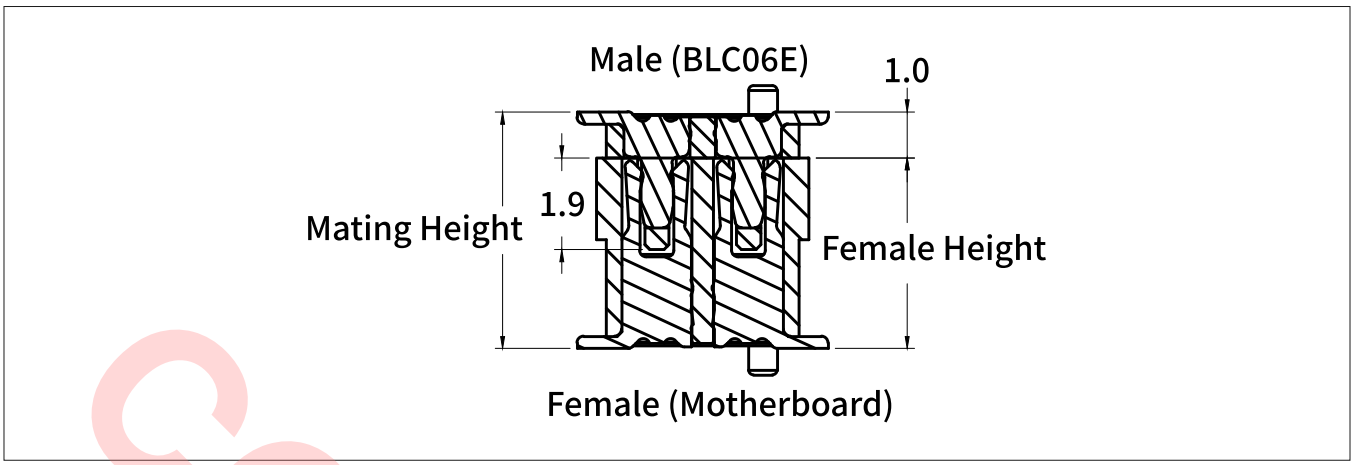


Figure 9: Onboard BTB Connector (Unit: mm)

The user's motherboard can use the female board-to-board connectors listed in the Table 8.

Table 8: Compatible Board-to-Board Connector Reference Table

Manufacturer	Series Model	Recommended Specific Model	Notes
HCTL	HC-PBB08-2-20-F	HC-PBB08-2-20-F-H3.0-G1-R-P-04	Recommended
Hanxia	HX-BTB F 08xx-2×10P	HX-BTB F0830-2x10P	
ZGWD	BB0800350F	BB0800350F-0202C-001	

4.2.2. Standoffs or SMT Standoffs

The BLC06E provides screw holes for securing to the user's motherboard. Users can fix it to standoffs or SMT standoffs using ISO M2 standard screws to ensure stable module installation.

The body dimensions of the standoffs or SMT standoffs should match the mating height of the selected BTB connector.

4.3. PCB Layout Guidelines

4.3.1. Recommended PCB Layout

Figure 10 shows the footprint diagram of the BLC06E module using the HCTL `HC-PBB08-2-20-F` series board-to-board connector.

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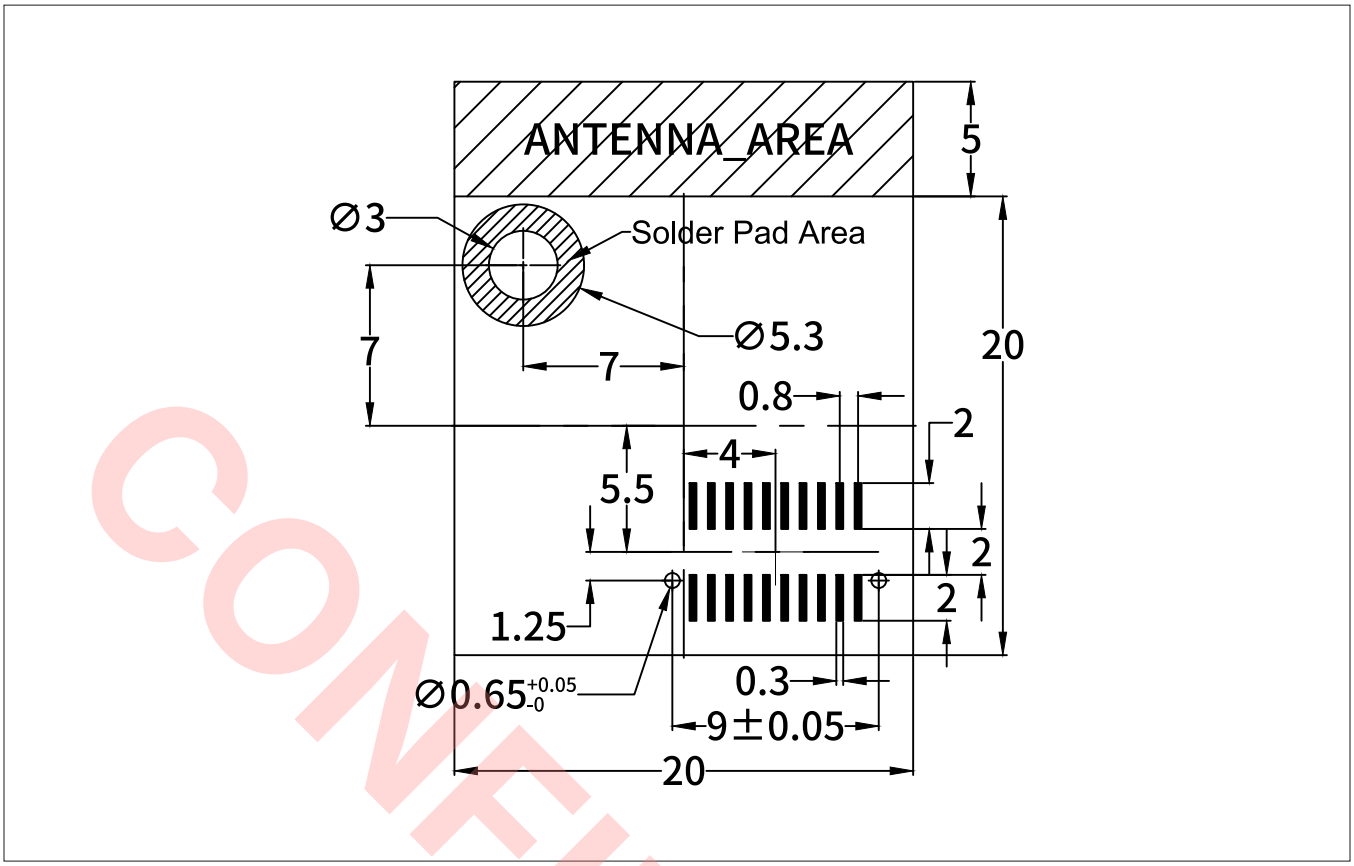


Figure 10: BLC06 Reference Footprint (Unit: mm)

If using SMT standoffs, refer to the specific product's datasheet. General design considerations include:

- The **solder pad area** needs to be controlled by the stencil aperture area to regulate the amount of solder paste, preventing solder from entering the bottom side of the PCB.
- The user's motherboard holes should use plated-through holes to increase soldering strength.

4.3.2. PCB Antenna Layout

Since the BLC06E module features an onboard PCB antenna, 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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4.3.3. PCB Layout Example

The appearance of the user's motherboard soldered with board-to-board connector SMT standoff is shown in Figure 11.

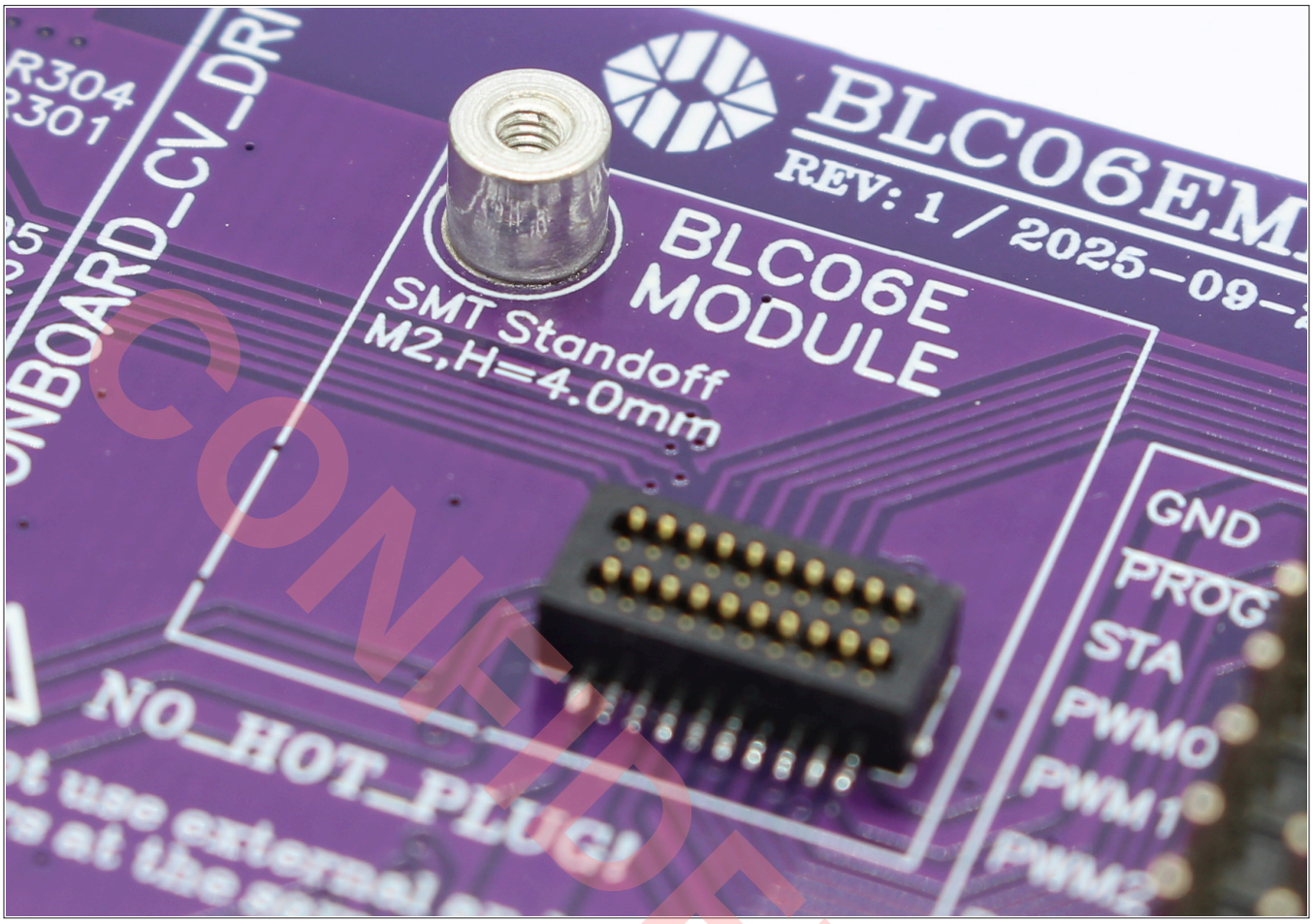


Figure 11: PCB Layout Example

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5. Product Handling

5.1. Product Storage and Usage

- The product should be stored in its sealed packaging, with storage temperature below 40°C.
- The product contains electrostatic-sensitive precision components; precautions should be taken to prevent electrostatic discharge during storage and use.

5.2. Product Cleaning

The product contains a quartz crystal oscillator internally; ultrasonic cleaning should not be performed, as it may cause equipment damage.

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6. Compliance and Environmental

6.0.1. RoHS Compliance Statement

When manufactured according to our Approved Vendor List (AVL) and using lead-free processes, this product complies with the EU RoHS Directive (EU) 2011/65/EU and its amendment (EU) 2015/863. The concentrations of the ten restricted substances (Pb, Hg, Cd, Cr6+, PBB, PBDE, DIBP, DEHP, DBP, BBP) in any homogeneous material do not exceed the applicable limits (Cd ≤ 0.01%, others ≤ 0.1%), unless a valid exemption is explicitly noted. No exemptions are claimed at this time unless otherwise stated.

6.0.2. REACH Compliance Statement

In accordance with REACH Regulation (EC) No 1907/2006, this product does not contain substances on the ECHA SVHC Candidate List, or such substances are present below 0.1% (w/w). We will notify customers within the legally required timeframe if supply-chain changes or ECHA updates affect this status.

6.0.3. Scope and Responsibility

This product is a module assembled by authorized contract manufacturers per our drawings and AVL. Final compliance is determined by the exact materials and processes used for each production lot. Lot-level compliance can be evidenced by supplier/CM Certificates of Compliance (CoC) and incoming inspection reports. Customers substituting materials or using other manufacturers should re-assess RoHS/REACH compliance.

6.0.4. Evidence (available upon request)

RoHS/REACH declarations of key components, declarations for PCB/ink/labels and lead-free solder, CM lot CoCs, and third-party test reports where applicable.

6.0.5. Regulatory Notes (RF)

- This product integrates a pre-certified radio module (Espressif ESP32-C3-MINI) with an on-module PCB antenna. The BLC06E as a whole has not been certified as a stand-alone radio product. The final device that integrates this module remains responsible for compliance with applicable regulations. Antenna substitution or modification is not supported.
- FCC (USA): Host devices must comply with FCC Part 15. Follow modular approval host-integration rules, including but not limited to: using only the integrated on-module PCB antenna as certified; maintaining required separation distances and antenna keep-out; affixing a label such as “Contains FCC ID: MODULE_FCC_ID” on the host; and including the required user information statements. Any enclosure, shielding, or mechanical changes that materially affect the antenna (e.g., metal standoffs or covers near the antenna) may require re-evaluation. Refer also to the PCB Antenna Layout guidance in this document.
- CE/RED (EU): Use of a pre-certified radio module does not exempt the host from RED (2014/53/EU) assessment. The final product must be assessed for radio, EMC, and safety as applicable. Changes to the antenna environment (metal proximity, enclosure, placement) may necessitate additional testing.
- For other regions (e.g., UKCA, Japan, etc.), host manufacturers should follow the corresponding local regulatory frameworks and labeling requirements.

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7. Related Resources

- **Official Website**
  www.borneoiot.com
- **Online Documentation**
  docs.borneoiot.com
- **GitHub Open-Source Project**
  github.com/borneo-iot

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9. Revisions

REV1 - 2025-09-25

Initial version.

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