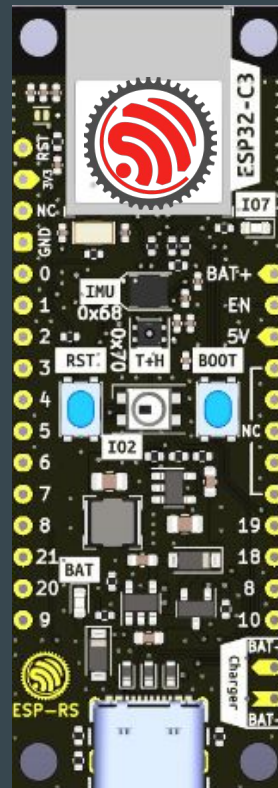
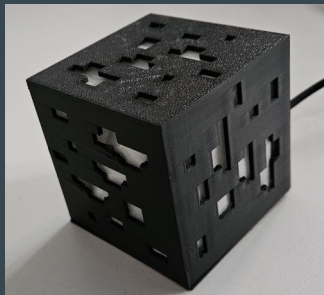




Rust on ESP32

2025-12-01
UNIZA - Žilina

Juraj Michálek
Espressif Systems

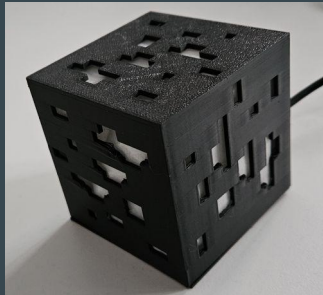


Embedded Projects

IoTcraft

Digital Twin in Voxel World

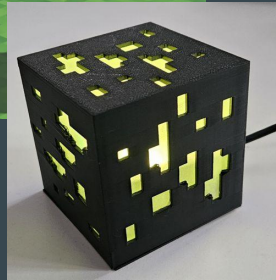
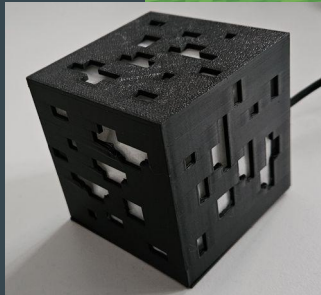
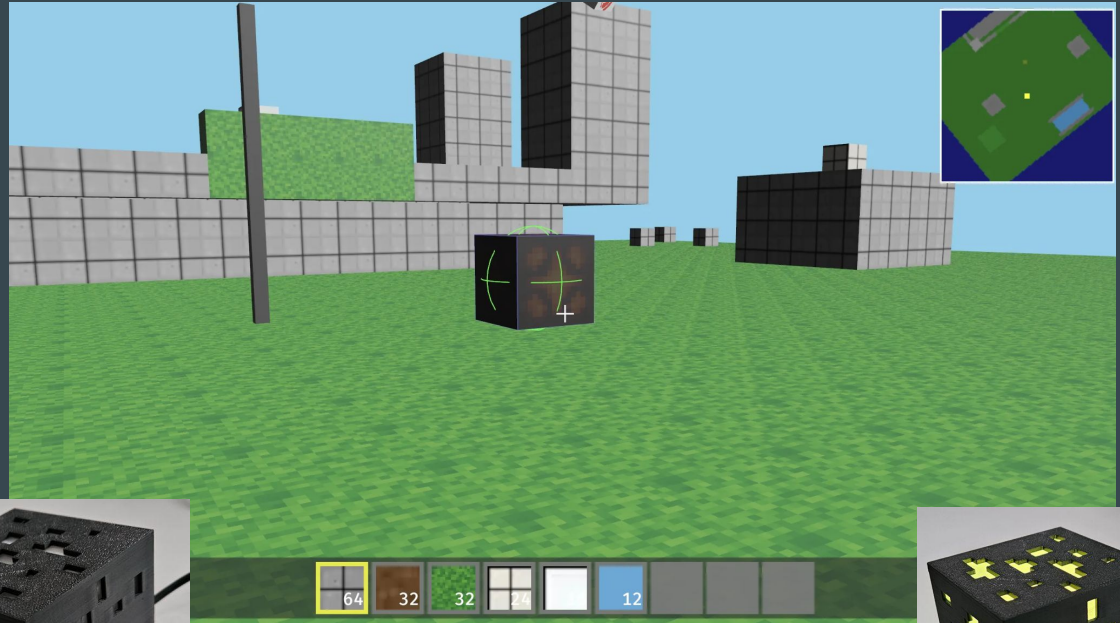
<https://github.com/georgik/iotcraft>



IoTcraft

Digital Twin in Voxel World

<https://github.com/georgik/iotcraft>



<https://developer.espressif.com>



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esp-hal 1.0.0 release announcement

30 October 2025 · 3 mins · 

Esp32

Rust

Xtensa

RISC-V

Announcement

AUTHOR

Scott Mabin

► Table of Contents

Announcing esp-hal 1.0, the first Rust SDK for embedded devices.

In February this year, we announced the first `esp-hal 1.0 beta` release. Since then we've been hard at work, polishing and preparing for the full release. Today, the Rust team at Espressif is excited to announce the official `1.0.0` release for `esp-hal`, the *first* vendor-backed Rust SDK!

Open Source - <https://github.com/esp-rs>



esp-rs

Libraries, crates and examples for using Rust on Espressif SoC's

README.md

Rust on Espressif microcontrollers

This organization is home to several projects enabling the use of the [Rust programming language](#) on various SoCs and modules produced by [Espressif Systems](#).

If you are just getting started writing Rust for ESP devices, please first read [The Rust on ESP book](#).

For a curated list of resources for development including tools and projects, see [Awesome ESP Rust](#).

Hardware Abstraction Layer

We offer two choices for Hardware Abstraction Layers:

Repository	Description	Support status
esp-rs/esp-hal	Without support for the Rust standard library (<code>no_std</code>)	Support status Official
esp-rs/esp-idf-hal	With support for the Rust standard library (<code>std</code>)	Support status Community

Rust no_std + esp-hal	
ROM functions	Registers
HW	

<https://github.com/esp-rs/esp-hal>

Official Espressif + Community Support

Requires Rust compiler

Bleeding edge MCUs and drivers might be missing

C wrapper app	Rust std + esp-idf-hal	
ESP-IDF		FreeRTOS
ROM functions	Registers	
HW		

<https://github.com/esp-rs/esp-idf-hal>

Community support

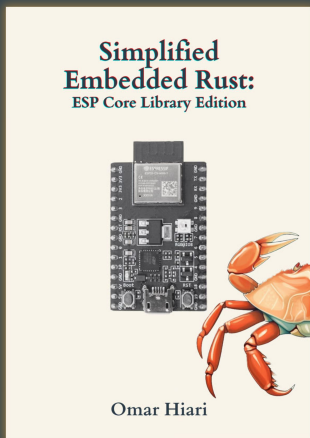
Requires Rust compiler + ESP-IDF

Bleeding edge MCUs and drivers from ESP-IDF

Training

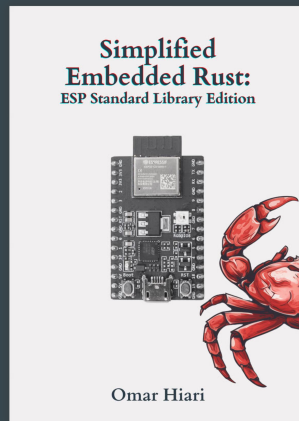
Rust no_std

- https://docs.espressif.com/projects/rust/no_std-training/
- https://github.com/esp-rs/no_std-training
- <https://www.theembeddedrustacean.com/c/ser-no-std>



Rust std

- <https://docs.esp-rs.org/std-training/>
- <https://github.com/esp-rs/std-training>
 - Created in cooperation with [Ferrous Systems](#)
- <https://www.theembeddedrustacean.com/c/ser-std>



RISC-V vs Xtensa

RISC-V

- newer
- ESP32-C, ESP32-H, ESP32-P
- upstream Rust compiler is sufficient

Xtensa

- older
- ESP32, ESP32-S2, ESP32-S3
- requires custom installation
- [espup install](#)



<https://www.espressif.com/en/products/longevity-commitment>

ESP Product Selector + Product Comparison

<https://products.espressif.com/>



ESP32-S3

ESP32-S3 is a low-power MCU-based SoC that supports 2.4 GHz Wi-Fi and Bluetooth® Low Energy (Bluetooth LE).

ESP32-S3 has a complete Wi-Fi subsystem and a Bluetooth LE subsystem. State-of-the-art power and RF performance. S3 provides a rich set of peripheral interfaces, and supports ultra-low-power applications. Different security features allow the device to meet stringent security requirements.

Features:

- Core: Xtensa® single-dual 32-bit LX7 CPU, frequency up to 240MHz
- Memories:

Block Diagram:



Product Brief

Docs & Certs

DevKits

List: 203 items

IC/Module

Development Board

Comparison

Export

☐	Index	Name	MPN	Marketing Status	Type	Wi-Fi
☐	1	ESP32-S3	ESP32-S3	Mass Production	SoC	IEEE 802.11 b/g/n; 2.4 ...
☐	2	ESP32-S3	ESP32-S3R2	Mass Production	SoC	IEEE 802.11 b/g/n; 2.4 ...
☐	3	ESP32-S3	ESP32-S3R8	Mass Production	SoC	IEEE 802.11 b/g/n; 2.4 ...
☐	4	ESP32-S3	ESP32-S3R...	Mass Production	SoC	IEEE 802.11 b/g/n; 2.4 ...
☐	5	ESP32-S3	ESP32-S3F...	Mass Production	SoC	IEEE 802.11 b/g/n; 2.4 ...

Product Selector | **Product Comparison**

Product Portfolio

Sales Questions

Technical Inquiries

Hide Same | **Show Same**

	ESP32-S3	ESP32-P4NRW16
Series	ESP32-S3	ESP32-P4
CPU	Xtensa® dual-core 32-bit LX7	32-bit RISC-V single-core processor
Freq. (MHz)	240	400
Package (mm)	QFN56 (7*7)	QFN10*10
Dimensions (mm)	7*7	10*10
Temp. (°C)	-40 °C ~ 105 °C	-40 °C ~ 85 °C
Status	Mass Production	Sample
ECO	standard version	
Support IDF	v0.x	

Quick start with AI at espressif.com

 **ESPRESSIF**

 **Espressif Docs AI**

How to create Hello world for ESP32-C6 in Rust no_std

To create a "Hello world" application for the ESP32-C6 in Rust using the `no_std` (bare-metal) approach, you should use the `esp-hal` crate, which provides hardware abstraction for Espressif chips in a `no_std` environment. The process involves generating a new project, configuring it for the ESP32-C6, and writing your application logic.

1. Generate a New Project

Espressif provides a project generation tool called `esp-generate` to bootstrap embedded Rust projects. To create a new project for ESP32-C6:

```
cargo install esp-generate
esp-generate --chip esp32c6 hello_world
```

This will scaffold a new Rust project set up for the ESP32-C6 in a `no_std` environment `esp-hal` 1.0.0 beta announcement.

2. Write the Application

A typical `no_std` "Hello world" for embedded is to blink an LED since there is no standard output. However, if you want to print to the serial console, you need to set up UART. The knowledge sources provide a blinky example for ESP32-C3,

Ask a follow-up

Deep thinking

Powered by  kapa.ai

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esp-generate --chip esp32c6

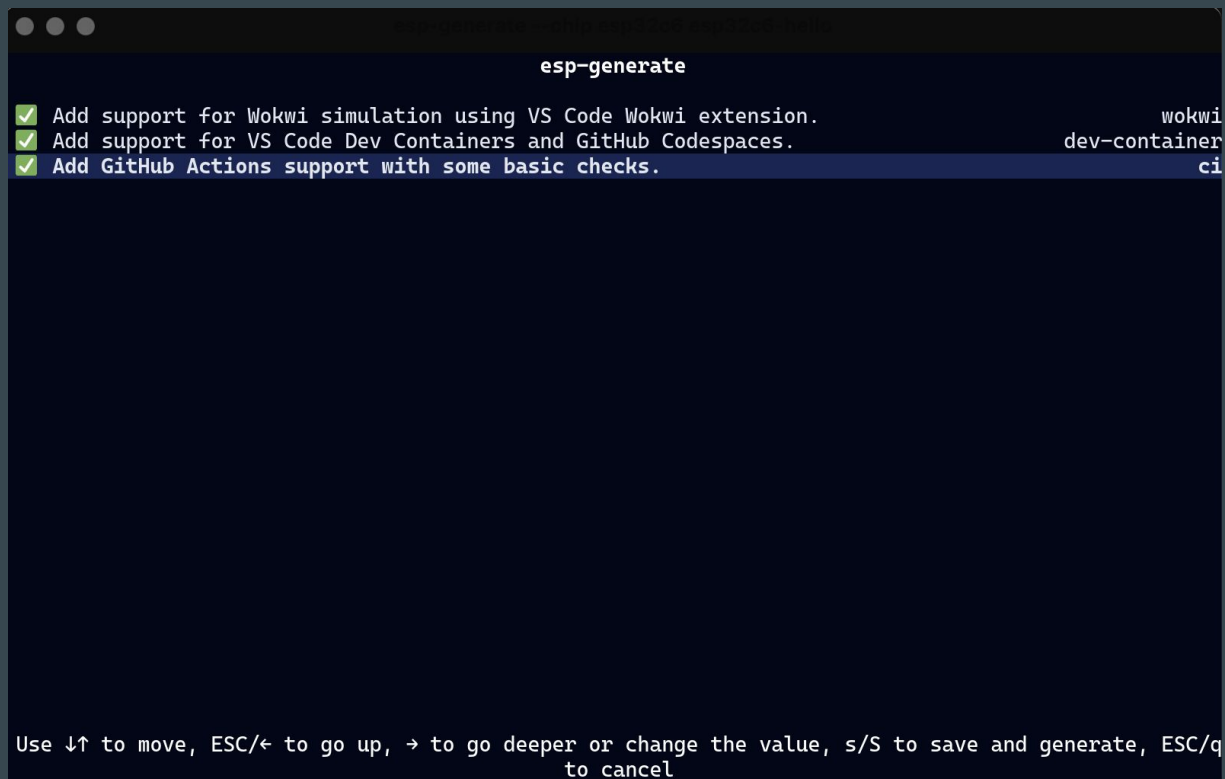
```
esp-generate --chip esp32c6 esp32c6-hello

esp-generate

[✓] Enable unstable HAL features.                                     unstable-hal
[✓] Enable allocations via the esp-alloc crate.                      alloc
[✓] Enable Wi-Fi via the esp-wifi crate.                             wifi
    Enable BLE via the esp-wifi crate (bleps).                      ble-bleps
    Enable BLE via the esp-wifi crate (embassy-trouble).           ble-trouble
[✓] Add embassy framework support.                                   embassy
[✓] Enable stack smashing protection.                               stack-smashing-protection
    Use probe-rs to flash and monitor instead of esptool.          probe-rs
▶ Flashing, logging and debugging (probe-rs)
▶ Flashing, logging and debugging (esptool)
▶ Options
▶ Optional editor integration

This configuration enables unstable esp-hal features. These come with no stability guarantees, and
could be changed or removed at any time. Required by `wifi` and `embassy`.
Use ↓↑ to move, ESC/← to go up, → to go deeper or change the value, s/S to save and generate, ESC/q
to cancel
```

esp-generate - more options



Build, flash, monitor

cargo run --release

shorter: cargo r -r

```
Build: Sep 19 2022
rst:0x1 (POWERON),boot:0xc (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:2
load:0x4086c410,len:0xd48
load:0x4086e610,len:0x2d68
load:0x40875720,len:0x1800
entry 0x4086c410
I (23) boot: ESP-IDF v5.1-beta1-378-gea5e0ff298-dirt 2nd stage bootloader
I (24) boot: compile time Jun 7 2023 08:02:08
I (25) boot: chip revision: v0.1
I (29) boot.esp32c6: SPI Speed      : 40MHz
I (33) boot.esp32c6: SPI Mode      : DIO
I (38) boot.esp32c6: SPI Flash Size : 4MB
I (43) boot: Enabling RNG early entropy source ...
I (49) boot: Partition Table:
I (52) boot: ## Label                Usage            Type ST Offset   Length
I (59) boot:  0 nvs                  WiFi data        01 02 00009000 00006000
I (67) boot:  1 phy_init             RF data          01 01 0000f000 00001000
I (74) boot:  2 factory              factory app      00 00 00010000 003f0000
I (82) boot: End of partition table
I (86) esp_image: segment 0: paddr=00010020 vaddr=42000020 size=0cc64h ( 52324) map
I (105) esp_image: segment 1: paddr=0001cc8c vaddr=40800000 size=00014h (   20) load
I (106) esp_image: segment 2: paddr=0001cca8 vaddr=4200cca8 size=4a5cch (304588) map
I (173) esp_image: segment 3: paddr=0006727c vaddr=40800014 size=0e324h ( 58148) load
I (187) esp_image: segment 4: paddr=000755a8 vaddr=40826f48 size=001e0h (   480) load
I (191) boot: Loaded app from partition at offset 0x10000
I (191) boot: Disabling RNG early entropy source ...
```

Simulation: Update wokwi.toml from debug to release

```
[wokwi]
```

```
version = 1
```

```
gdbServerPort = 3333
```

```
#elf = "target/riscv32imac-unknown-none-elf/release/esp32c6-hello"
```

```
firmware = "target/riscv32imac-unknown-none-elf/release/esp32c6-hello"
```

CLion with Rust plugin or RustRover

The screenshot displays the CLion IDE interface with a Rust project named 'esp32c6-hello'. The main.rs file is open, showing the following code:

```
30 async fn main(spawner: Spawner) {
31
32     println!("Hello, ESP32!");
33
34     let timer0 : SystemTimer = SystemTimer::new(peripherals.SYS_TIMER);
35     esp_hal_embassy::init(timer0.alarm0);
36
37
38
39
40
41
42
43
44     let rng : Rng = esp_hal::rng::Rng::new(peripherals.RNG);
45     let timer1 : TimerGroup<TIMG0> = TimerGroup::new(peripherals.TIMG0);
46     let wifi_init : EspWifiController = esp_wifi::init(timer1.time_base);
47     .expect(msg: "Failed to initialize WIFI/BLE controller");
48     let (mut _wifi_controller, _interfaces) = esp_wifi::wifi::new_with_timeouts();
49     .expect(msg: "Failed to initialize WIFI controller");
50
51     // TODO: Spawn some tasks
52     let _ = spawner;
53
54     loop {
55         Timer::after(Duration::from_secs(1)).await;
56     }
57
58     main()
59 }
```

The Wokwi Simulator window shows a virtual ESP32-C6 board with various pins connected. The board is labeled 'ESP32-C6' and has pins for TX, RX, SDIO, and others. The simulator is running at 80% speed.

The bottom status bar shows the current file path: 'esp32c6-hello > src > bin > main.rs' and the current function: 'main()'. It also displays the Cargo Check status, file encoding (UTF-8), and other details.

Open Source - <https://github.com/espressif>

[Overview](#) [Repositories 294](#) [Projects 5](#) [Packages](#) [Teams 15](#) [People 34](#) [Sponsoring 2](#)



Espressif Systems

Verified Sponsor

6.3k followers Shanghai, China <http://espressif.com>

README.md

Welcome to Espressif's site on GitHub

Espressif supports a large variety of open-source projects, including SDKs, components, libraries, solutions, and tools, which aim to help developers bring their projects to life.

All of Espressif's official software, relating to the various series of ESP SoCs including ESP32 and ESP8266, are available on this GitHub site. To check out all the series of SoCs from Espressif, please visit our [ESP Product Selector](#).

Below you can find a selection of Espressif's open-source projects. Our full repository list can be found [here](#).

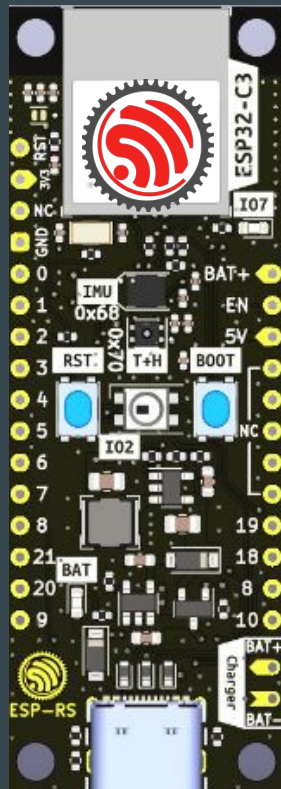
Open Hardware - esp-rust-board

KiCad templates

<https://github.com/esp-rs/esp-rust-board>

ESP32-C3-DevKit-RUST-1

<https://www.espressif.com/en/products/devkits>



Rust tooling in Rust

- <https://github.com/esp-rs/espup> - installing and maintaining the required toolchains
- <https://github.com/esp-rs/espflash> - Serial flasher utilities for Espressif devices
- <https://github.com/esp-rs/esp-generate> - Template generation tool to create no_std applications
- <https://github.com/espressif/idf-im-ui> - A cross-platform graphical user interface for installing based on Tauri
- <https://github.com/georgik/espbrew> - Remote flashing



Slint

Quick prototyping

Free and commercial version



Example: List of WiFi networks

Rust std

Rust no_std

Rust no_std + Embassy

<https://github.com/georgik/esp32-list-wifi-networks/>

Bevy ECS (Entity Component System)

One of biggest open source Rust projects

- <https://bevyengine.org/>

Rust no_std + Bevy ECS

- <https://developer.espressif.com/blog/2025/04/bevy-ecs-on-esp32-with-rust-no-std/>
- <https://github.com/georgik/esp32-spooky-maze-game>



Rust Bare Metal - Embedded Graphics



Source: <https://github.com/georgik/esp32-spooky-maze-game>

Idea: sharing business logic in Rust between
multiple targets

Game is using Bevy ECS no_std.



<https://github.com/espressif/esp-box>

rs-matter



license **Apache2** CI **passing** crates.io **v0.1.0** m join matrix 43 users

What is it exactly?

A pure-Rust, `no_std`, no-alloc, async-first, extensible and safe implementation of the [Matter protocol](#).

Scales from bare-metal MCUs with 1MB flash and 256KB RAM to ARM embedded Linux and bigger iron!

Rather than a shrink-wrapped solution, it is first and foremost - a **toolkit**. Users are free to consume all of the APIs, including the provided system clusters, or only pick up bits and pieces. As in:

- ... re-using the transport layer and Secure Channel, but implementing their own Data Model;
- ... custom Exchange responders;
- ... custom mDNS provider;
- ... custom IP network implementation and BLE GATT device implementation;
- ... flexible polling of the `rs-matter` futures as e.g. separate tasks in their async executor of choice;
- ... or just using the shrink-wrapped [rs-matter-stack](#) arrangement and its down-stream crates;
- ... and so on.

<https://github.com/project-chip/rs-matter>

rainmaker-rs



Rust Implementation of ESP Rainmaker

A cross-platform implementation of ESP Rainmaker for ESP32 products and Linux using Rust.

- ESP RainMaker is end-to-end IoT development platform which enables development of IoT applications which can be controlled remotely.
- However, the C based ESP RainMaker SDK(which can be found [here](#)) only supports execution on Espressif's ESP32 SOC's.
- This crate tries to implement similar functionalities for Linux platform along with ESP32(which can further be extended to other microcontrollers).

What is working

- ☑ WiFi Provisioning*:
Providing WiFi for a new device. No need to hardcode WiFi credentials!
- ☑ Remote Control:
Controlling Devices connected to a node over internet using phone application.
- ☑ User Node Association:
Associating a specific node to a user account for control.
- ☑ Device sharing:
Share access to a device with multiple members.
- ☑ Control using Home Assistants:
RainMaker devices can be added to and controlled using Amazon Alexa / Google Home. More details [here](#)

* Currently only supported on ESP32

<https://github.com/rainmaker-rs/rainmaker>

OSes and integration



Rust no_std - <https://github.com/esp-rs/esp-hal> - official support

Rust std - <https://github.com/esp-rs/esp-idf-hal> - community support

Ariel OS - <https://ariel-os.github.io/ariel-os/dev/docs/book/>



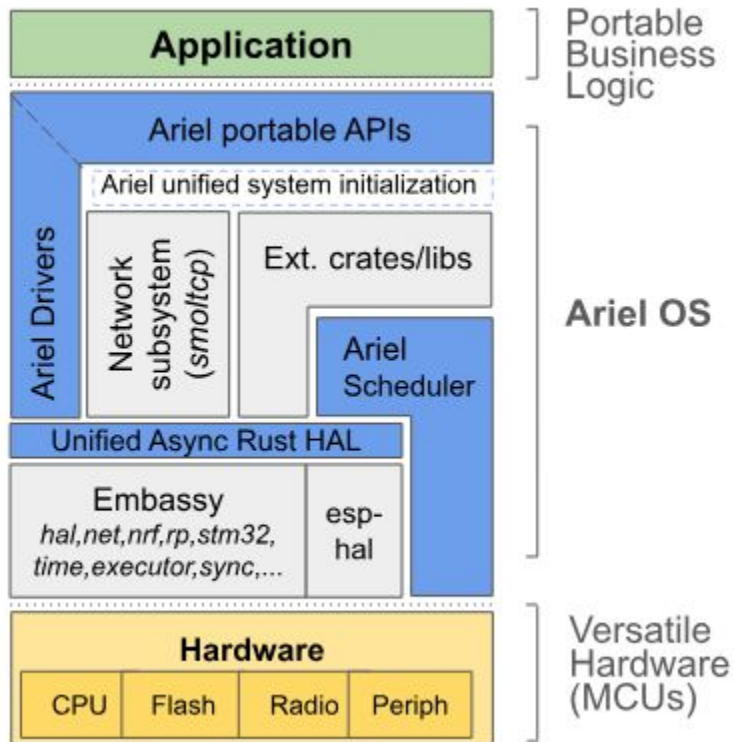
Zephyr - <https://zephyrproject.org/>

NuttX - <https://nuttx.apache.org/>



SVD files: <https://github.com/espressif/svd>

Ariel OS



<https://ariel-os.github.io/ariel-os/dev/docs/book/>

IDE for Rust development

Supported by Espressif:

- VS Code with Espressif Extension - <https://developer.espressif.com/tags/vscode/>



Supported by JetBrains:

- CLion - <https://developer.espressif.com/blog/clion/>
- RustRover - <https://www.jetbrains.com/rust/>



Developer Portal

developer.espressif.com

GitHub: <https://github.com/espressif/developer-portal/>

The screenshot displays the Espressif Developer Portal website. At the top, the navigation bar includes the Espressif logo, the text "Developer Portal", and links for "Blog", "Workshops", "Events", "Quick Links", and a search icon. The main content area is titled "Rust" and features several article cards:

- Rust no_std & Bevy ECS**: A card with a dark background and a circuit board image. It includes the title "Bevy Entity Component System on ESP32 with Rust no_std", the date "9 April 2025", a duration of "6 mins", and tags: "Embedded Systems", "ESP32", "ESP32-S3", "ESP32-C3", "Rust", "Bevy", "No_std", "ECS", and "WASM".
- esp-hal 1.0.0 beta announcement**: A card with the Espressif logo. It includes the title "esp-hal 1.0.0 beta announcement", the date "24 February 2025", a duration of "11 mins", and tags: "ESP32", "Rust", "Xtensa", "RISC-V", and "Announcement".
- Simplified Embedded Rust: A Comprehensive Guide to Embedded Rust Development**: A card with two book covers. It includes the title "Simplified Embedded Rust: A Comprehensive Guide to Embedded Rust Development", the date "7 June 2024", a duration of "3 mins", and tags: "Rust", "Embedded Systems", "ESP32", "ESP32-C3", "Espressif", "Wokwi", "Book", and "Review".
- Rust + Embedded: A Development Power Duo**: A card with the Espressif logo. It includes the title "Rust + Embedded: A Development Power Duo", the date "19 April 2023", a duration of "11 mins", and tags: "Rust", "Embedded Systems", "ESP32", and "Rust Programming Language".
- Rust on Espressif chips — 18-10-2021**: A card with the Espressif logo. It includes the title "Rust on Espressif chips — 18-10-2021", the date "17 October 2021", a duration of "6 mins", and tags: "ESP32", "Rust", and "Xtensa".

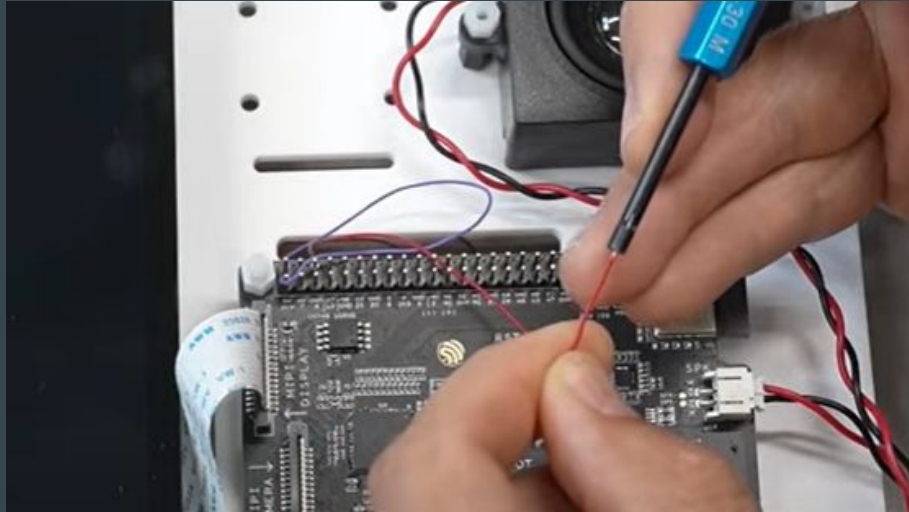
How to “unbrick” ESP32

Many people incorrectly thinks that ESP32 is bricked, in many cases the custom firmware just does not receive UART or USB signals.

Solution: hold BOOT button and press RESET to switch to boot mode

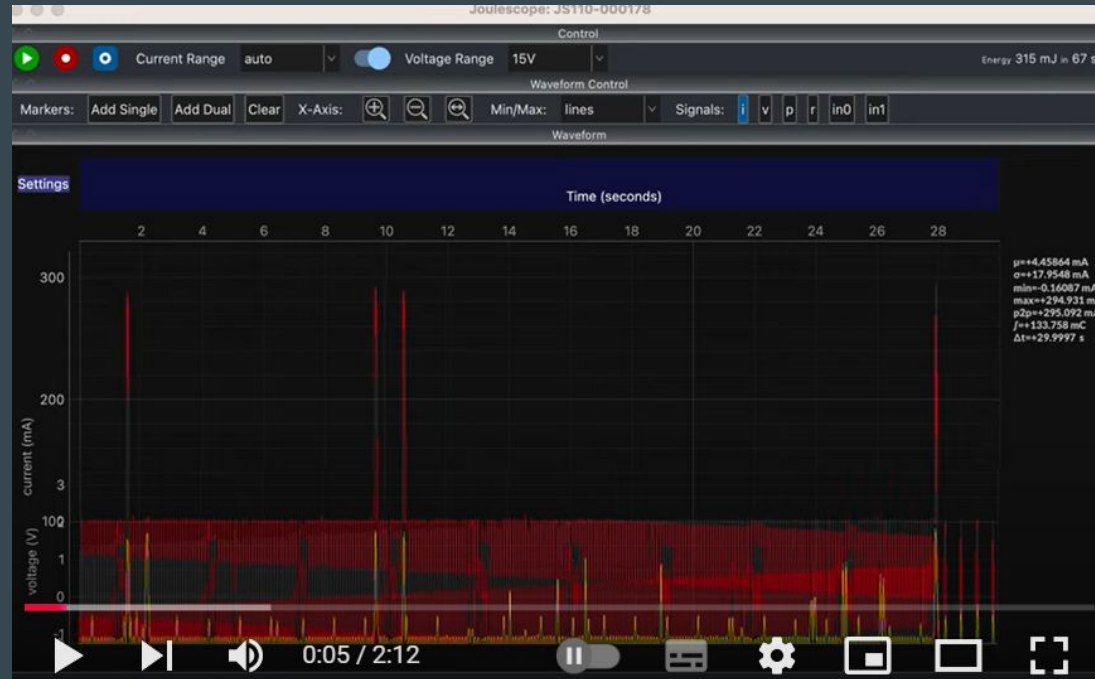
After flashing, just press RESET to return to normal mode.

Wire Wrap Tool



Espressif DevCon 2024 - Tips and Tricks

ESP32-C6 TWT



<https://www.youtube.com/watch?v=FA1jqZLig4s>

Espressif Developer Conference 2022-2024 - recording



<https://www.youtube.com/@EspressifSystems>

<https://devcon.espressif.com/>

Embedded World 2026

Meet us in Nuremberg, Germany



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Exhibition&Conference

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ESPRESSIF

Prototyping With Espressif Chips

Try it with ESP Launchpad

ADF, IDF, and Other SDKs

Insights from Espressif Engineers

Automation With Rainmaker and Matter

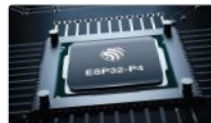
Trying Out the ESP32-S3-BOX-3

ESP32 and ChatGPT

In this issue

- > An Open-Source Speech Recognition Server
- > Power Duct: Rust + Embedded
- > Facial Recognition With ESP32-S3-EYE
- > Walkie-Talkie with ESP-NOW
- > Another Elektor Christmas Tree Project

and much more!



Unleashing the ESP32-P4
The Next Era of Innovative
Microcontrollers

p. 59



Acoustic Fingerprinting
Song Recognition With ESP32

p. 80



A Vision for the AIoT
Interview with Espressif CEO
Teo Swee-Ann

p. 35



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<https://www.elektor.com/products/elektor-special-espessif-guest-edition-2023-pdf-en>

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