

# ESP32

Dual-Core Wi-Fi & Bluetooth SoC — Technical Datasheet



## Overview

The ESP32 is a feature-rich, low-cost System-on-Chip (SoC) developed by Espressif Systems. It integrates a dual-core Xtensa LX6 32-bit processor, 2.4 GHz Wi-Fi (802.11 b/g/n), Bluetooth Classic and BLE 4.2, along with a rich set of peripherals — making it ideal for IoT, wearables, industrial control, and connected embedded systems.

## Key Features

- Dual-core Xtensa LX6 @ up to 240 MHz
- 2.4 GHz Wi-Fi 802.11 b/g/n (up to 150 Mbps)
- Bluetooth Classic + BLE 4.2
- 34 programmable GPIO pins
- 12-bit ADC (18 channels), 8-bit DAC (2 channels)
- Hardware SPI, I2C, I2S, UART, CAN, PWM
- Ultra-low-power co-processor (ULP)
- 520 KB SRAM, supports external flash up to 16 MB

## At a Glance

CPU	Cores	Clock	SRAM	Wi-Fi	Bluetooth	GPIO	Op. Voltage
Xtensa LX6	2 (+ ULP)	240 MHz	520 KB	802.11 b/g/n	BT 4.2 + BLE	34	3.3V

# Electrical Specifications

## Absolute Maximum Ratings

Exceeding these values may permanently damage the device.

Parameter	Min	Typical	Max	Unit
Supply Voltage (VDD)	2.3	3.3	3.6	V
Input Voltage on GPIO	-0.3	—	3.6	V
DC Current per GPIO	—	—	40	mA
Total GPIO Current (all pins)	—	—	1200	mA
Storage Temperature	-40	—	150	°C
Operating Temperature	-40	25	85	°C
ESD Voltage (HBM)	—	—	2000	V
Flash Write Endurance	—	100,000	—	cycles

## DC Characteristics (VDD = 3.3V, T = 25°C)

Parameter	Symbol	Min	Typ	Max	Unit
Supply Voltage	VDD	2.3	3.3	3.6	V
GPIO High-Level Output	VOH	2.64	3.3	—	V
GPIO Low-Level Output	VOL	—	0.1	0.33	V
GPIO High-Level Input	VIH	0.75×VDD	—	VDD	V
GPIO Low-Level Input	VIL	0	—	0.25×VDD	V
Internal Pull-Up Resistance	RPU	30	45	75	kΩ
Internal Pull-Down Resistance	RPD	30	45	75	kΩ

## Power Consumption

Mode	Typical Current	Notes
Active (Wi-Fi TX)	~240 mA peak	802.11n, 72 Mbps, +17 dBm
Active (Wi-Fi RX)	~100 mA	Receiving mode
Active (BLE TX)	~130 mA peak	BLE advertising
Modem Sleep	~20 mA	CPU active, RF off
Light Sleep	~0.8 mA	CPU paused, RTC + ULP active
Deep Sleep (RTC on)	~10 μA	RTC memory & co-processor active
Deep Sleep (ULP on)	~150 μA	ULP co-processor running
Power Off / Hibernation	~5 μA	Only RTC timer active

# Pin Reference & I/O

## GPIO Overview

The ESP32 provides 34 physical GPIO pins. Not all pins are available on all modules — refer to your specific module's pinout. GPIO 6–11 are internally connected to the SPI flash and must not be used. GPIOs 34–39 are input-only with no internal pull-up/pull-down.

GPIO	Input	Output	Alt Functions	Notes
0	Yes	Yes	ADC2_CH1, CLK_OUT1, Touch 1	Boot mode select — pull-up at boot
1	TX0	Yes	CLK_OUT3, EMAC_RXD2	UART0 TX — used for serial monitor
2	Yes	Yes	ADC2_CH2, Touch 2, HSPIWP	Must be LOW at boot for flash mode
3	Yes	RX0	CLK_OUT2	UART0 RX — used for serial monitor
4	Yes	Yes	ADC2_CH0, Touch 0, EMAC_TX_CLK	General purpose
5	Yes	Yes	VSPICS0, EMAC_RX_CLK, HS1_DATA6	HIGH at boot
12	Yes	Yes	ADC2_CH5, Touch 5, MTDI, HSPIQ	Boot fail if pulled HIGH
13	Yes	Yes	ADC2_CH4, Touch 4, MTCK, HSPID	General purpose
14	Yes	Yes	ADC2_CH6, Touch 6, MTMS, HSPICLK	Outputs PWM at boot
15	Yes	Yes	ADC2_CH3, Touch 3, MTDO, HSPICS0	Outputs PWM at boot
16	Yes	Yes	HS1_DATA4, U2RXD, EMAC_CLK_OUT	UART2 RX
17	Yes	Yes	HS1_DATA5, U2TXD, EMAC_CLK_180	UART2 TX
18	Yes	Yes	VSPICLK, HS1_DATA7	SPI CLK (VSPI)
19	Yes	Yes	VSPIQ, U0CTS, EMAC_TXD0	SPI MISO (VSPI)
21	Yes	Yes	VSPIHD, EMAC_TX_EN	I2C SDA (default)
22	Yes	Yes	VSPiWP, U0RTS, EMAC_TXD1	I2C SCL (default)
23	Yes	Yes	VSPID, HS1_STROBE	SPI MOSI (VSPI)
25	Yes	Yes	ADC2_CH8, DAC_1, EMAC_RXD0	DAC Channel 1
26	Yes	Yes	ADC2_CH9, DAC_2, EMAC_RXD1	DAC Channel 2
27	Yes	Yes	ADC2_CH7, Touch 7, EMAC_RX_DV	General purpose
32	Yes	Yes	ADC1_CH4, Touch 9, XTAL_32K_P	RTC GPIO, 32 kHz crystal
33	Yes	Yes	ADC1_CH5, Touch 8, XTAL_32K_N	RTC GPIO, 32 kHz crystal
34	Input only	—	ADC1_CH6, RTC_GPIO4	No internal pull-up/down
35	Input only	—	ADC1_CH7, RTC_GPIO5	No internal pull-up/down
36	Input only	—	ADC1_CH0, RTC_GPIO0	No internal pull-up/down
39	Input only	—	ADC1_CH3, RTC_GPIO3	No internal pull-up/down

# Peripherals & Communication Interfaces

## Communication Interfaces

Interface	Count	Default Pins	Max Speed	Notes
UART	3	UART0: GPIO1(TX), GPIO3(RX)	5 Mbps	UART0 used for programming/debug
SPI	4 (2 usable)	VSPI: GPIO23/19/18/5	80 MHz	HSPI & VSPI free for user; SPI0/1 reserved
I2C	2	GPIO21 (SDA), GPIO22 (SCL)	400 kHz	Any GPIO via remapping
I2S	2	Configurable	40 MHz	Audio input/output support
CAN (TWAI)	1	Configurable	1 Mbps	ISO 11898-1 compatible
PWM (LEDC)	16 ch	Any GPIO	40 MHz	16-bit resolution, 8 timers
MCPWM	2 units	Configurable	—	Motor control PWM
PCNT	8 units	Configurable	—	Pulse counter units
RMT	8 ch	Configurable	—	IR remote / WS2812 LEDs

## ADC & DAC

Peripheral	Channels	Resolution	Reference	Notes
ADC1	8 ch (GPIO32–39)	12-bit (0–4095)	1.1V internal	Safe to use with Wi-Fi
ADC2	10 ch (various)	12-bit (0–4095)	1.1V internal	Conflicts with Wi-Fi — use ADC1 when Wi-Fi active
DAC1	1 ch (GPIO25)	8-bit (0–255)	3.3V VDD	True analog output ~0–3.3V
DAC2	1 ch (GPIO26)	8-bit (0–255)	3.3V VDD	True analog output ~0–3.3V

## Memory Architecture

Memory	Size	Type	Notes
Internal SRAM	520 KB	Volatile	512 KB data + 8 KB RTC SRAM
RTC SRAM (Fast)	8 KB	Volatile	Accessible by main CPU and ULP
RTC SRAM (Slow)	8 KB	Volatile	Accessible by ULP during deep sleep
Internal ROM	448 KB	Non-volatile	Bootloader and core library code
External Flash (QSPI)	Up to 16 MB	Non-volatile	Module-dependent; typically 4 MB
External PSRAM (QSPI)	Up to 8 MB	Volatile	Optional; some modules include 4 MB
eFuse	1024 bits	OTP	Stores MAC, security keys, config bits

## Wi-Fi & Bluetooth Specifications

Parameter	Specification
Wi-Fi Standard	802.11 b/g/n (2.4 GHz)
Wi-Fi Speed	Up to 150 Mbps (HT40)
Wi-Fi Modes	Station, SoftAP, Station+AP



Wi-Fi Security	WPA/WPA2/WPA3, WPS
Bluetooth Version	v4.2 BR/EDR + BLE
BLE TX Power	Up to +9 dBm
BLE Sensitivity	-97 dBm
Antenna	PCB trace antenna (on-module); optional external via U.FL

# Mechanical & Reference

## Module Dimensions (ESP32-WROOM-32)

Dimension	Value	Notes
Module Length	18 mm	Standard WROOM-32 footprint
Module Width	31.4 mm	Includes PCB antenna overhang
Module Height	3.3 mm	Excluding pins
Pitch (castellated pads)	1.27 mm	38 pads total around perimeter
Operating Voltage	3.3V	Regulated; do not connect 5V directly to GPIO
Dev Board Width (DevKitC)	~28 mm	Fits across 400-point breadboard with space
Dev Board Length (DevKitC)	~48.3 mm	Including USB connector overhang
Weight (module only)	~3 g	WROOM-32 module
Antenna Keep-Out Zone	3.3 × 16 mm	No copper/ground pours under PCB antenna

## Supported Frameworks & Programming

Framework	Language	Toolchain	Notes
Arduino Core (ESP32)	C/C++	Arduino IDE / PlatformIO	Easiest entry point; large library ecosystem
ESP-IDF (official)	C/C++	Xtensa GCC / CMake	Full hardware access; FreeRTOS-based
MicroPython	Python	esptool + MicroPython firmware	Rapid prototyping; limited performance
CircuitPython	Python	UF2 bootloader	Beginner-friendly; limited ESP32 support
Lua (NodeMCU)	Lua	NodeMCU firmware	Lightweight scripting for IoT
Rust (esp-rs)	Rust	esp-idf-hal crate	Memory-safe systems programming

## Regulatory Compliance

Certification	Status	Region
FCC (ID: 2AC7Z-ESP32WROOM32)	Certified	United States
CE	Certified	European Union
IC	Certified	Canada
MIC / TELEC	Certified	Japan
KC	Certified	South Korea
RoHS	Compliant (Pb-free)	Worldwide

## References

- ESP32 Technical Reference Manual: [espressif.com/documentation/esp32\\_technical\\_reference\\_manual\\_en.pdf](https://www.espressif.com/documentation/esp32_technical_reference_manual_en.pdf)
- ESP32 Datasheet: [espressif.com/sites/default/files/documentation/esp32\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf)
- ESP-IDF Programming Guide: [docs.espressif.com/projects/esp-idf/en/latest/esp32](https://docs.espressif.com/projects/esp-idf/en/latest/esp32)

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- Arduino ESP32 Core: [github.com/espressif/arduino-esp32](https://github.com/espressif/arduino-esp32)
  - ESP32 WROOM-32 Module Datasheet: [espressif.com/documentation/esp32-wroom-32\\_datasheet\\_en.pdf](https://espressif.com/documentation/esp32-wroom-32_datasheet_en.pdf)
  - voltX.dev Resources: [voltX.dev](https://voltX.dev)

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