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MEASURING POWER AND BATTERY RUNTIME

Runtime is capacity divided by average draw, discounted for the usable fraction and the regulator loss. How to measure real current and why sleep current dominates battery life.

ONE THOUSAND DRONES ENGINEERING TEAM · VERIFIED 2026-07

Runtime is capacity divided by average draw, with an honest discount for the voltage window you can actually use and the power the regulator loses. Guess the draw and you get a fantasy; measure it and you get a number you can trust. This guide, and the calculator below, do it the honest way.

AVERAGE DRAW IS WHAT COUNTS

Runtime is set by the average current, not the peaks. A board that sleeps at `20 uA` and wakes for a `100 mA` burst once a minute averages far closer to the sleep figure than the burst. Add up the current over a full cycle of the board's behavior and divide by the time to get the true average.

THE RUNTIME ESTIMATE

Start with the capacity, multiply by the fraction of it you can actually reach before the cell hits its empty voltage, then divide by the average draw. The usable fraction is never one: a regulator stops working below its dropout, and a lithium cell is empty at `3.0 V`, not `0 V`, so a real board reaches perhaps 80 percent of the printed capacity.

$$t = (Q \times \text{usable-fraction}) / I_{avg}$$

CALCULATOR · LIPO BATTERY RUNTIME CALCULATOR (ESP32 / MICROCONTROLLER)

Estimate runtime from battery capacity, average current draw, and usable capacity. Worked from a real ESP32-S3 board's measured budget.

Interactive calculator: academy.onethousanddrones.com/tools/lipo-battery-runtime

ESTIMATE RUNTIME FROM CAPACITY, AVERAGE DRAW, AND THE USABLE FRACTION.

EFFICIENCY AND REGULATOR LOSS

Every regulator between the cell and the load takes a cut. An LDO wastes the voltage it drops; a switcher loses a fixed percentage; a boost draws more current from the cell than the load ever sees. Fold that loss into the average draw at the battery, not at the load, or the estimate runs long.

MEASURING THE REAL CURRENT

You cannot estimate what you have not measured. Put a meter in series with the supply and read the current in each state, asleep and awake. For the tiny sleep current a plain multimeter often lacks resolution, so a low-value sense resistor or a dedicated power analyzer reads the microamps that decide a battery board's life.

CAPACITY TIMES THE USABLE FRACTION, DIVIDED BY THE AVERAGE DRAW, GIVES THE HOURS.

WHY SLEEP CURRENT DOMINATES BATTERY LIFE

On most battery boards the board is asleep almost all the time and awake for a few milliseconds now and then. That means the sleep current, not the flashy active burst, sets how long the battery lasts. Halving a `100 uA` sleep current can nearly double the runtime, while shaving the active burst barely moves it. When a design must last months on a cell, the whole fight is the sleep number.

DEEP DIVE · SELF-DISCHARGE AND COLD, THE SLOW LEAKS

Two effects erode runtime that no current meter on the load will ever show. A cell self-discharges, slowly losing charge on its own even with nothing connected, so a board that sleeps for months loses capacity to the cell as much as to the load. And cold cuts capacity: a lithium cell delivers noticeably less charge in the cold than at room temperature, because the chemistry slows down. For a board that must last a season outdoors, budget both, or the bench estimate will beat the field every time.

- Battery University. BU-503 (usable design capacity fades to 70 to 80 percent of rated). batteryuniversity.com
- Espressif. ESP32-S3 Series Datasheet (deep-sleep current consumption). espressif.com

CHECKPOINT

1. What dominates the battery life of a board that is mostly asleep?

a. The brief active burst

b. The sleep or idle current

c. The battery's nominal voltage

ANSWER · B

With the board asleep almost all the time, the sleep current sets the runtime.

2. Why is real runtime less than capacity divided by draw?

a. The usable fraction is below one and the regulator loses power

b. Batteries always outperform their rating

c. Current meters read high

ANSWER · A

You cannot use the whole capacity, and the regulator between cell and load takes a cut.

3. How do you measure a board's true current draw?

a. Read the battery's printed label

b. Guess from the datasheet maximums

c. Put a meter in series with the supply and read each state

ANSWER · C

Measure asleep and awake; the tiny sleep current often needs a sense resistor or a power analyzer.

- Prerequisite: batteries 101
- Calculate it: the LiPo battery runtime calculator
- See it on a real board: the L2.01 battery power module