LIBRARY · REFERENCE GUIDE

BUCK REGULATORS (STEP-DOWN)

A buck regulator steps voltage down efficiently by switching instead of burning the difference as heat. The topology, how duty cycle sets the output, and when to pick a buck.

ONE THOUSAND DRONES ENGINEERING TEAM · VERIFIED 2026-07

A buck regulator steps a voltage down without cooking a regulator. Instead of burning the excess voltage as heat, it switches the input on and off fast and filters the result, so almost all the energy reaches the output. It is how you get `3.3 V` from a `12 V` input efficiently.

HOW SWITCHING AVOIDS THE HEAT

An LDO wastes the voltage it drops as heat. A buck does not drop voltage across a resistor at all. It chops the input into pulses with a fast switch, then smooths those pulses back into a steady lower voltage with an inductor and a capacitor. Little is wasted, so a buck can be over 90 percent efficient where an LDO doing the same big step-down would be far worse.

THE BASIC BUCK

A buck is a switch, an inductor, a second switch or a diode, and an output capacitor. The switch feeds the inductor in pulses; the inductor stores energy in its magnetic field and hands it to the output smoothly; the capacitor holds the output steady between pulses. The controller adjusts the timing to keep the output on target.

DUTY CYCLE SETS THE OUTPUT

The fraction of each cycle the main switch is on is the duty cycle, and for a buck it sets the output as that fraction of the input. Fifty percent of `12 V` gives `6 V`; a smaller duty cycle gives a lower output. The controller trims the duty cycle continuously to hold the output fixed as the input and load move.

$$V_{out} = D \times V_{in}$$

THE SWITCH CHOPS THE INPUT; THE INDUCTOR AND CAPACITOR SMOOTH IT INTO A LOWER STEADY VOLTAGE.

DEEP DIVE · RIPPLE, AND WHY THE INDUCTOR AND CAPACITOR MATTER

A buck's output is not perfectly flat. Each switching cycle leaves a small sawtooth called ripple riding on the DC. The inductor and the output capacitor set how large that ripple is: a bigger inductor holds the current steadier, a bigger capacitor absorbs more of the wobble. The same fast switching that makes a buck efficient also radiates noise, which is why a switching supply needs careful layout and sometimes a filter, and why a noise-sensitive analog rail is sometimes fed by a small LDO placed downstream of the buck.

- Texas Instruments. Basic Calculation of a Buck Converter's Power Stage (SLVA477). ti.com

CHECKPOINT

1. Why is a buck more efficient than an LDO for a big step-down?

a. It sheds the wasted power through a bigger heatsink

b. It switches and filters instead of burning the difference as heat

c. It drops the extra voltage across a larger resistor

ANSWER · B

A buck stores and transfers energy through an inductor rather than dropping it across a pass element.

2. Which two parts smooth a buck's chopped input into a steady output?

a. An inductor and a capacitor

b. Two resistors

c. A transformer and a diode

ANSWER · A

The inductor stores energy and the output capacitor holds the voltage steady between pulses.

3. In a buck, the duty cycle sets what?

a. The output ripple amplitude only

b. The switching frequency only

c. The output as a fraction of the input

ANSWER · C

Vout = D x Vin: the on-fraction of each cycle sets the output level.

- Prerequisite: linear regulators (LDO)
- Next: boost regulators (step-up)
- See also: LDO vs switcher, picking one