Dynamo

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Visit the Shimano DH-C3000-3N Hub Dynamo on Amazon.
Visit the LM2596 Step-down DC-DC Buck Converter

Visit the TP4056 for Li-Ion Battery

1 Structure of the Dynamo

A dynamo is a small electrical generator that converts the kinetic energy of the bicycle (usually through wheel rotation) into electrical energy. The dynamo produces alternating current (AC), which must first be converted to direct current (DC) using a rectifier. After that, a smoothing electrolytic capacitor is connected in parallel to the rectifier's output to reduce voltage ripple, though the voltage is not yet perfectly stable. Finally, a voltage regulator stabilizes the voltage to a fixed level, e.g., 5 volts.

2 Types of Dynamos

1. Sidewall dynamo (classic, mounted on the tire side)
2. Hub dynamo (integrated into the front wheel — more modern and efficient)

3 Advantages

- No need to charge or replace batteries or accumulators.
- Power is available as long as you are riding — ideal for long distances or daily commuting.
- No battery waste — energy is produced purely by muscle power.
- A well-built dynamo can last for many years.
- In many countries, dynamo lighting is permitted and even recommended for bicycles.

4 Disadvantages

- Especially with sidewall dynamos, you feel slight resistance when riding (requires more effort).
- Without an energy buffer, the rear light only works while riding — unless buffer capacitors or batteries are used.
- Dynamos may slip in rain or snow.
- High-quality hub dynamos are more expensive and must be built into the wheel.

5 Hub Dynamo

- Type: 6 V / 3 W hub dynamo (standard, e.g., Shimano DH-3N31)
- The hub dynamo supplies alternating current (AC) $\rightarrow$ the rear light and battery require direct current (DC)
- Hub dynamo voltage varies with speed (typically 5–12 V)

Property	Schottky Diode (e.g., 1N5819)
Reverse voltage	approx. 40 V (completely sufficient)
Forward voltage V_f	only about 0.2–0.45 V
Switching speed	Fast (ideal for smoothing capacitors and digital circuits)
Suitability for dynamo use	Excellent – low losses, higher usable output voltage

Table 1: Advantages of Schottky diodes for dynamo-powered rectifier circuits

6 Energy Storage

1. Supercapacitors (Supercaps): Supercapacitors can store energy to power the rear light while stationary. Supercaps usually have a low voltage (approx. 2.7 V per cell) and a smaller capacity than batteries, so the standby duration is short (seconds to a few minutes, depending on size).
2. Battery/Accumulator: e.g., a lithium-ion or LiPo battery. While riding, the hub dynamo generates power, which is first converted from AC to DC by a rectifier. Then the voltage is stabilized by a voltage regulator, and the regulated power charges the battery through a charging circuit, such as a TP4056 module.

7 Bridge Rectifier and Smoothing Capacitor (Electrolytic Capacitor)

7.1 Bridge Rectifier

7.2 Why Schottky Diodes are Ideal for Hub Dynamo Circuits

Schottky diodes have significant advantages over standard rectifier diodes, especially in low-voltage applications such as hub dynamos. The following table summarizes the most important properties:

7.3 Smoothing Capacitor (Electrolytic Capacitor)

Which capacitance?
The required capacitance depends on three factors:
– The current drawn by the microcontroller
– The rectified frequency (hub dynamo typical: approx. 17 Hz rotation frequency)
– The output voltage of the dynamo

7.4 Rule of Thumb for the Smoothing Capacitance

To estimate the needed capacitance for a smoothing capacitor after a rectifier, the following rule of thumb applies:

$$C \approx \frac{I}{f \cdot \Delta U} \tag{1}$$

Where:

- C – capacitance in farads (F)
- I – load current (µC + LED current) in amperes (A) (approx. 20 mA per LED)
- f – ripple frequency after rectification (Hz)
  For a full-wave rectifier: $f = 2 \times f_{generator}$
- ΔU – maximum allowed ripple voltage (V)

$$C = \frac{0.24A}{... \cdot 1V} \tag{2}$$

7.4.1 Why is a Ripple Voltage ΔU of 1 V Often Assumed?

The ripple voltage ΔU defines the tolerated voltage variation after the smoothing capacitor. A value of approximately 1 V is a good compromise because:

– It provides sufficiently smooth voltage for the voltage regulator to operate stably.
– Smaller values require significantly larger (and more expensive) capacitors.
– Larger values allow too much fluctuation, making the circuit unstable.

Hence, $\Delta U = 1\,\mathrm{V}$ is a practical rule of thumb for sizing smoothing capacitors.

7.5 Voltage Regulator

A voltage regulator is an electronic component that delivers a constant output voltage regardless of input or load variations.

Why do you need a voltage regulator?

- The dynamo produces a fluctuating voltage that, even after rectification and smoothing, may still vary and often exceed 5 V.
- Your ATtiny requires a stable and safe 5 V supply.
- Without a voltage regulator, components could be damaged or operate erratically.

7.5.1 Selection Criteria for Voltage Regulators

Input Voltage After rectification and smoothing, your dynamo may output between about 7 V and 15 V depending on speed. The regulator must tolerate this input range.

Output Voltage The ATtiny requires a stable 5 V.

Current Demand Estimate your circuit's total current draw (ATtiny 300 µA, LEDs may draw much more). The regulator must handle the maximum expected current.

7.5.2 Use: LM2596 Module

- Converts input voltage from 4–40 V to an adjustable output voltage of 3.3–24 V
- Maximum output current up to 3 A

7.6 Charging Management

The charging management module protects the battery from overcharge, deep discharge, etc.

7.6.1 Selected:

TP4056

Energy Flow Diagram

- Dynamo (AC)
- ↓ Rectifier
- ↓ Smoothing Capacitor
- ↓ Voltage Regulator
- ↓ Battery Management
- ↓ Battery (e.g., Li-Ion)
- Load (ATtiny + LED)