Understanding eFuse ICs for Circuit Protection

1. Introduction to Powering Circuits Safely

When finalizing an electronics project, selecting the **right power source** is crucial. A **USB port and power banks** are often recommended because they:

- Provide **stable 5V power**.
- Include **built-in protection** against **short circuits and reverse voltage**.
- Offer **portability** and ease of use.

However, for circuits powered by **batteries, solar panels, or custom power sources**, additional **protection mechanisms** are needed to prevent **undervoltage, overvoltage, reverse voltage, and overcurrent issues**.

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2. Why Use an eFuse IC?

An **eFuse IC (Electronic Fuse)** provides:

- **Undervoltage Protection** – Prevents operation when voltage drops below a safe level.
- **Overvoltage Protection** – Limits excessive voltage that could damage components.
- **Overcurrent Protection** – Prevents excessive current draw that could cause overheating or failure.
- **Thermal Protection** – Stops operation if the device overheats.

Example Use Case: LiPo Supercharger Circuit

- This circuit outputs **5V and 12V**, but must be **protected against short circuits and overcurrent events** to prevent damage.
- Using an **eFuse IC** ensures **safe and reliable operation** for connected devices.

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3. Selecting an eFuse IC

3.1 Where to Find eFuse ICs

- eBay offers limited options.
- Reliable sources include **Mouser, Digi-Key, and other electronics distributors**.

3.2 Defining Protection Requirements

For an **Arduino Nano project**, the following parameters were chosen:

- **Overvoltage Limit:** Above **6V**.
- **Undervoltage Limit:** Below **4V**.
- **Current Limit: 200mA** (enough for the project but low enough to prevent damage).

3.3 Choosing the Right IC: TPS259621

- Supports **2.7V to 19V** input voltage.
- Adjustable **current limit from 0.125A to 2A**.
- Includes **overvoltage and undervoltage protection**.
- Comes in a **hand-solderable package**.
- **Cost:** Around **$0.86 USD**, making it a budget-friendly option.

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4. Wiring the eFuse IC

Basic Connections

- **GND pin → Ground of the circuit.**
- **IN pin → Input voltage source (e.g., battery, power supply).**
- **OUT pin → Circuit that needs protection.**

Configuring Protection Features

4.1 Setting the Undervoltage Limit

- The **Enable/Undervoltage (EN/UV) pin** determines when the circuit turns on or off.
- A **100kΩ pull-up resistor** ensures the IC is enabled.
- Using a **resistor divider network**, the undervoltage pin was set to:
    - **Turn ON the circuit at 4.5V.**
    - **Cut off power below 4V.**

4.2 Setting the Overvoltage Limit

- By default, the IC clamps **overvoltage to 13.58V**.

- For a **5.7V threshold**, a **400kΩ resistor to GND** is used.
- In testing, using a **470kΩ resistor** successfully **clamped voltage to 5.35V**.
- Excess voltage is dissipated as **heat**, but the IC includes **over-temperature protection** to prevent failure.

4.3 Setting the Current Limit

- The **ILM (Current Limit) pin** is used to control **maximum allowable current**.
- A resistor is used to **set the current threshold** based on the formula in the datasheet.
- In this case, a **200mA limit** was set, and testing confirmed the current did not exceed this value.

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5. Additional Features of the eFuse IC

5.1 Fault Pin

- Indicates when a **protection event occurs** (e.g., overcurrent, undervoltage).

5.2 dV/dt Pin (Inrush Current Limiting)

- Connecting a **capacitor** to this pin **gradually increases output voltage**, reducing **sudden current surges** when the circuit is powered on.

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6. Adding Reverse Voltage Protection

- The **TPS259621 eFuse IC does not include reverse voltage protection**.
- A **P-Channel MOSFET** was used to prevent **reverse polarity damage**.
- When tested, the MOSFET successfully **blocked reverse voltage**, ensuring circuit safety.

Alternative Solution

- More advanced **eFuse ICs with built-in reverse voltage protection** exist but are harder to solder.

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7. Conclusion: Why Use an eFuse IC?

- **Affordable and Easy to Use** – Requires only a few external resistors.

- **Multi-Layer Protection** – Covers **overvoltage, undervoltage, overcurrent, and thermal protection**.
- **Better than Traditional Fuses** – Unlike physical fuses, **eFuses reset automatically** after a fault condition.
- **Prevents Circuit Damage** – Essential for battery-powered and high-power applications.

Final Thoughts

- For **general electronics projects**, an **eFuse IC like the TPS259621** is a **cost-effective and reliable protection solution**.
- For **higher power applications**, **customized protection circuits** or **higher-rated eFuses** may be needed.
- A **P-Channel MOSFET** can be added for **reverse voltage protection**.