Resettable Fuses in Electronics

Introduction to Overcurrent Protection

Mistakes in circuit building such as reverse voltage, incorrect pin connections, or component failures can lead to overcurrent, which is a critical issue that can cause permanent damage like explosions or fires. To mitigate these risks, overcurrent protection is necessary.

- **Glass Fuses**: Traditional fuses interrupt current when excessive flow occurs, but they need to be replaced once blown.
- **Resettable Fuses**: Unlike glass fuses, resettable fuses (also known as Polyfuses, Multifuses, or PPTCs) can reset after the overcurrent condition is resolved, making them reusable and ideal for certain applications like electronic devices, where fuses cannot be replaced easily.

Types of Resettable Fuses

1. **Through-Hole Resettable Fuses**: Easier to work with in DIY and prototyping scenarios.
2. **Surface-Mounted Devices (SMD) Resettable Fuses**: Found in commercial products like the Raspberry Pi.

PPTC (Polymeric Positive Temperature Coefficient) Device:

- The main function of PPTCs is to increase resistance as temperature rises, which halts excessive current flow.
- **Comparison with NTC (Negative Temperature Coefficient) devices**: NTC devices decrease resistance with increasing temperature and are commonly used in 3D printers to measure temperature.

Choosing a Resettable Fuse

When selecting a resettable fuse, four key properties must be considered:

1. **Maximum Voltage**: The highest voltage the fuse can withstand without being damaged.
2. **Maximum Current**: The highest current that can flow through the fuse without failure.
3. **Hold Current**: The current level that can flow continuously without tripping the fuse.
4. **Trip Current**: The current level at which the fuse activates to interrupt the circuit.

Example Selection:

- For a 12V, 500mA circuit (e.g., RGB LED strip), a suitable fuse with a **hold current of 0.5A** and **trip current of 1A** is selected to protect the circuit.

Testing a Resettable Fuse

- **Setup**: A constant load circuit powered by 12V is used to test the fuse.
- **Procedure**: The current is gradually increased, and the voltage drop across the fuse is monitored.
    - **Hold Current Test**: At 500mA, the fuse remains unaffected and does not trip.
    - **Trip Current Test**: At 1A, the fuse's resistance rises, interrupting the current flow after approximately 26 seconds.

Comparison with Traditional Fuses:

- Traditional fuses take longer to activate under the same conditions, making resettable fuses more efficient for handling overcurrent scenarios.

Testing a High-Current Load

- A larger power resistor is used to simulate a higher current load (1.2A) to test the fuse under real-world conditions.
- **Result**: The fuse limits the current to approximately 103mA, demonstrating its ability to prevent damage, though the current is not fully cut off like in traditional fuses. The fuse enters a high-resistance state, reducing the risk of damage.

Leakage Current:

- Even when the fuse is tripped, a small amount of current (leakage current) flows through, which keeps the fuse in its high-resistance state and causes it to remain heated.

Additional Measurements and Observations

- **Power Losses**:
    - When tripped, the resettable fuse consumes power (1.2W), which is more than stated in the datasheet.

    - Larger fuses have slightly less power loss under normal operation but waste more power when tripped.

- **Response Between Hold and Trip Currents**:
    - At intermediate currents (e.g., 700mA), the fuse might not immediately trip. However, at higher currents (e.g., 900mA), the fuse trips quicker.
    - The fuse becomes conductive again once the current decreases, but its resistance takes longer to return to normal after being tripped.

Applications of Resettable Fuses

- **Battery Packs**: PPTCs are often used to protect battery packs because they trip when they overheat, preventing damage from overheating or short circuits.
- **General Electronics Protection**: PPTCs can protect components like capacitors, transistors, or even power supplies from overcurrent damage.

Comparing Resettable Fuses to Other Types

- **Traditional Glass Fuses**: Efficient, low power losses, but not reusable.
- **eFuses**:
    - eFuses trip faster and more precisely, but are more expensive, require more complex setup, and are not resettable.
    - eFuses offer better performance but are limited in voltage and current range compared to resettable fuses.
- **Resettable Fuses (PPTCs)**:
    - Ideal for applications where resetting is necessary.
    - Can handle higher currents and voltages than traditional fuses and eFuses, but might not be as efficient in terms of power losses.

Conclusion

- Resettable fuses are a great option for applications where protection and reuse are required. They are versatile, cost-effective, and ideal for devices that are prone to overcurrent conditions.
- The choice of fuse (resettable, traditional, or eFuse) depends on the specific application needs, balancing cost, efficiency, and complexity.