

Comprehensive Overview of Current Mirrors

Introduction

Current mirrors are essential in analog circuit design, used to replicate current from one part of a circuit to another with high fidelity. This document provides an exploration of current mirrors, including their operation principles, types, applications, and advancements.

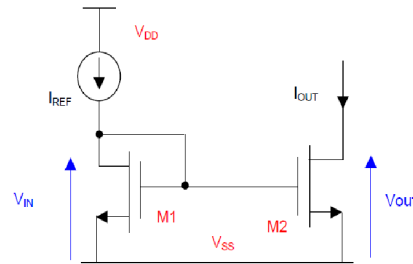


Figure1: Basic current mirror circuit

Principles of Operation

A current mirror replicates a current through one active device by controlling the current in another, maintaining a constant output current regardless of loading. It typically involves two transistors: a reference transistor and a mirroring transistor. The circuit uses feedback to maintain the mirrored current. If the output current deviates, the resulting voltage change adjusts the base voltage, correcting the current. Also, by altering emitter areas or using different transistor sizes, the output current can be scaled to a desired multiple of the reference current.

Types of Current Mirrors

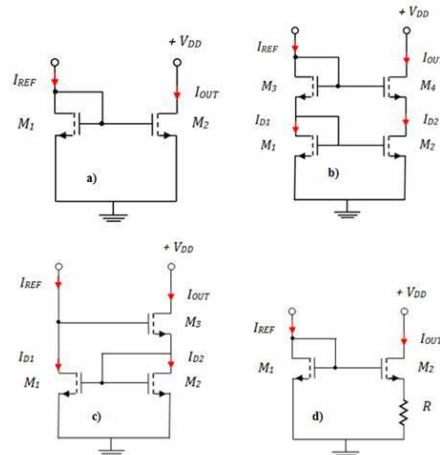


Figure2: Basic current mirror circuits. a) Simple current mirror SCM, b) Cascode current mirror CCM, c) Wilson current mirror WilsonCM, d) Widlar current mirror WidlarCM.

a) Simple Current Mirror: Uses two matched transistors with the base and collector of one transistor connected to ensure it operates in the active region. The emitter of the second transistor provides the mirrored current.

- **Advantages:** Simplicity, ease of implementation, and low component count.
- **Disadvantages:** Limited accuracy due to base current and Early effect, moderate output resistance.

b) Wilson Current Mirror: Introduces an additional transistor to improve output resistance and accuracy.

- **Advantages:** High output resistance, improved accuracy, and temperature stability.
- **Disadvantages:** Increased complexity and component count.

c) Cascode Current Mirror: Uses a cascode configuration to significantly enhance output resistance and reduce voltage dependence.

- **Advantages:** Extremely high output resistance, improved performance in high-frequency applications.
- **Disadvantages:** Requires higher supply voltage (more headroom), increased circuit complexity.

d) Wide-Swing Current Mirror: Designed to operate efficiently over a wide range of output voltages, addressing limitations in low-voltage applications.

- **Advantages:** Operates effectively at low supply voltages, high output resistance.
- **Disadvantages:** More complex design considerations.

Applications

Current mirrors are extensively used in various analog circuits:

- **Operational Amplifiers:** Used in differential stages and active loads to enhance gain and linearity.
- **Analog-to-Digital Converters (ADCs):** Ensure precise current replication for accurate digital conversion.
- **Voltage References:** Provide stable currents necessary for generating consistent voltage references.
- **Biasing Circuits:** Set the operating points of transistors in various analog circuits.
- **Sensor Interfaces:** Convert sensor outputs into proportional currents, which are easier to process and measure.

Advancements and Challenges

Modern current mirrors address challenges such as temperature stability, transistor mismatch, and high output resistance through advanced techniques:

- Compensation techniques mitigate the effects of temperature variations on current mirroring accuracy.
- Precision matching and layout techniques, along with trimming procedures, minimize transistor mismatches.
- Cascode configurations and active feedback mechanisms achieve higher output resistance.

Design Considerations

Several factors must be considered for optimal performance in current mirror design:

- **Transistor Matching:** Ensuring closely matched characteristics is crucial for accurate current replication.
- **Power Supply Rejection Ratio (PSRR):** High PSRR maintains a constant output current despite variations in the supply voltage.
- **Headroom Requirements:** Minimizing voltage headroom is essential, especially in low-voltage applications.

Conclusion

Current mirrors are indispensable in analog circuit design, offering a reliable method for current replication with minimal components. Their versatility and efficiency make them crucial in numerous applications, from amplifiers to voltage references.