

## Base Current Compensation in Bipolar Current Mirrors Using a Darlington Pair Configuration

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### Abstract

This paper presents a unique base current compensation methodology used for a bipolar current mirror circuit (CMC). In this basic CMC, the base current is compensated using a Darlington pair circuit. The current mirror circuit is a fundamental building block in analog and mixed-signal circuits and play a critical role in current mode signal processing and various applications. The output performance of the proposed circuit was analyzed using a Q-SPICE simulator, and the output terminal current was found to be a mirror of the input terminal current.

**Keywords**— Current mirror circuit, Darlington pair, Base Current Compensation, BJT, Q-SPICE.

## 1. Introduction

In current mirror circuit output current is independent of the output terminal voltage but on the input current [1]. The input current is copied at the output terminal using a transistor pair. The current mirror circuit have ability to modify current by amplifying and attenuated it by varying the area of the transistor [3]. It is a two-terminal device and basic building blocks used in electronics circuit design today. It also known as current regulate the current source. Current mirror circuits are essential building blocks used in the construction of operational amplifiers. An ideal current source has infinite output impedance to deliver constant current regardless of output voltage. In BJT-based current mirrors, base current reduces the accuracy of the mirrored output, prompting the development of various compensation techniques [4].

This paper presents a unique method that combine Darlington pair circuit with basic current mirror circuit for compensation of base current and output terminal current mirror follow the input terminal current. It did not change the output resistance of the circuit. Darlington pair technique uses super beta  $\beta_x\beta_y$  (if all physical parameter is same  $\beta_x\beta_y = \beta$ ) to compensate the base current of the circuit.

CMC is used as a source of active load in a variety of applications, such as op-amp, single stage amplifier, data converters, current convey etc [5]. The proposed circuit improved CMC configuration designed to provide a more constant current source or sink and it provide more accurate input and output current gain.

## 2. Literature Review

In this section, discuss various current mirror survey based on their performance like output current, output resistance etc. Simple current mirror circuit are simple in design, fabrication and analysis but having issue of considerable amount of base current drawn or sink by both transistors and get difference on input and output terminal current, the circuit also have low output impedance [6]. The cascode current mirror circuit improved the performance of the output impedance but there is still base current issue and it affecting the input and output current, the Wilson current mirror improves the output resistance and also reduce the base current by  $\beta$  and output terminal current improved [7].

This paper presents a simple and unique method to improve the output terminal current with negligible dependency on  $\beta$  and maintains constant output resistance. The proposed model also express in mathematical and prove that the output current is mirror of input terminal current. The circuit performance is simulated through Q SPICE simulator

### 3. Methodology

In the modern integrated circuit design, current mirror circuits play a critical role in maintaining precise current matching and biasing in various analog and mixed-signal circuits [8]. Design a BJT based Darlington pair current mirror circuit that accurately replicates a reference current as shown in figure 1. Consider all transistor operating in saturation mode and Q1 and Q2 draw or sink base current  $I_{b1}=I_{b2}$ .

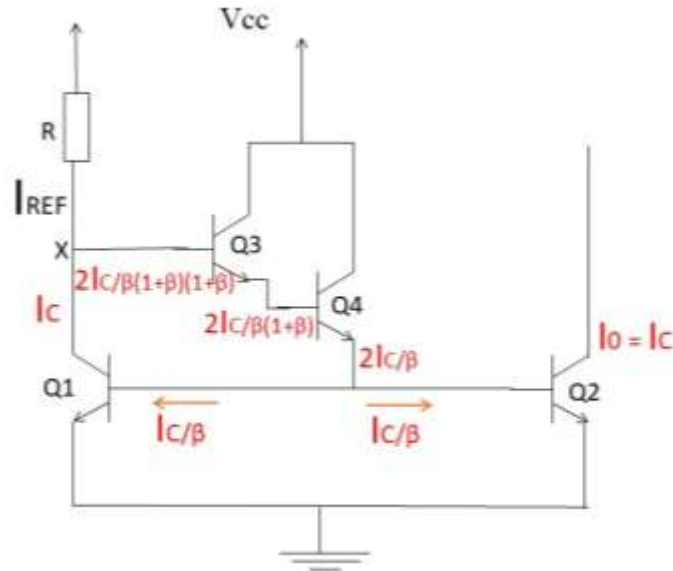


**Figure 1: Darlington pair used to compensate base current**

Here  $R$  is the required resistance of the proposed model and it can be found from equation (1).

$$R = \frac{V_{DD} - V_{BE1} - V_{BE3} - V_{BE4}}{I_{REF}} \quad (1)$$

If all physical parameters of the transistors are equal, then we consider same base to emitter voltage as  $V_{BE1} = V_{BE2} = V_{BE}$  and  $I_{B1} = I_{B2} = I_B = I_C / \beta$  then required R value as shown in equation (2).

$$R = \frac{V_{DD} - V_{3BE}}{I_{REF}} \quad (2)$$

The Darlington pair output (emitter) current is  $2I_c/\beta$  and we know that the base current draw is  $2I_c/\beta(1+\beta)(1+\beta)$ . The  $I_{ref}$  of the current mirror circuit is a combination of  $I_c$  and base current of Darlington pair circuit as shown in equation (3).

$$\text{IREF} = \text{IC} + 2 \frac{\text{IC}}{\beta(1+\beta)(1+\beta)} \quad (3)$$

We know  $\beta \gg 1$  therefore  $(1+\beta) = \beta$

$$\text{IREF} = \text{IC} + 2 \frac{\text{IC}}{\beta^3}$$

We know that  $\frac{\text{IC}}{\beta^3}$  is very small number and we consider it is zero.

Therefore

$$I_{REF} = I_C = I_O \quad (4)$$

The equation (4) shows the circuit acts as more accurate current mirror compared to other existing BJT circuits and output resistance ( $R_{out}$ ) remains constant and is not affected by this modification.

#### 4. Simulation Result of Circuit

Figure 2 shows the simulation circuit combination of basic Darlington circuit with basic current mirror circuit. The simulation voltages were measured across the collector terminal of the Q1 and Q2 as representing node by N1 and N2 and measure collector current by Ic(Q1) and Ic(Q2). Simulation results are shown in Figure 3, indicating that the output terminal current mirrors the input terminal current and also shown the voltage drop across collector terminal of the circuit.

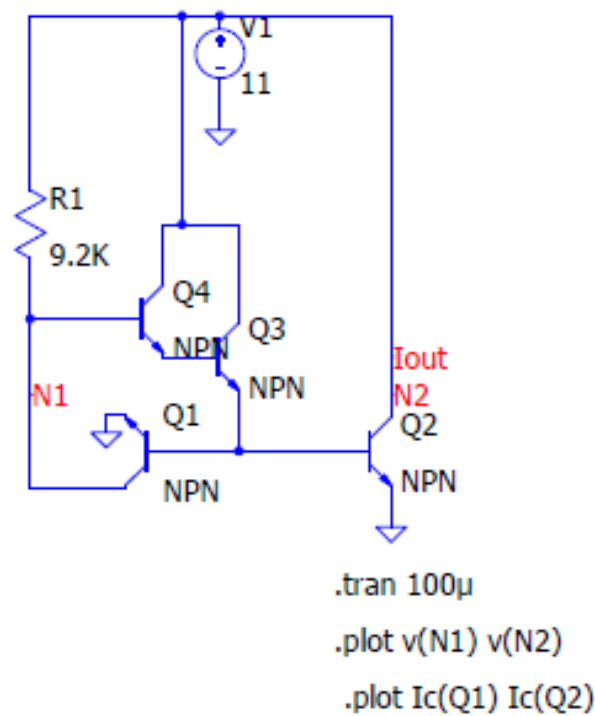


Figure 2: Simulation Circuit

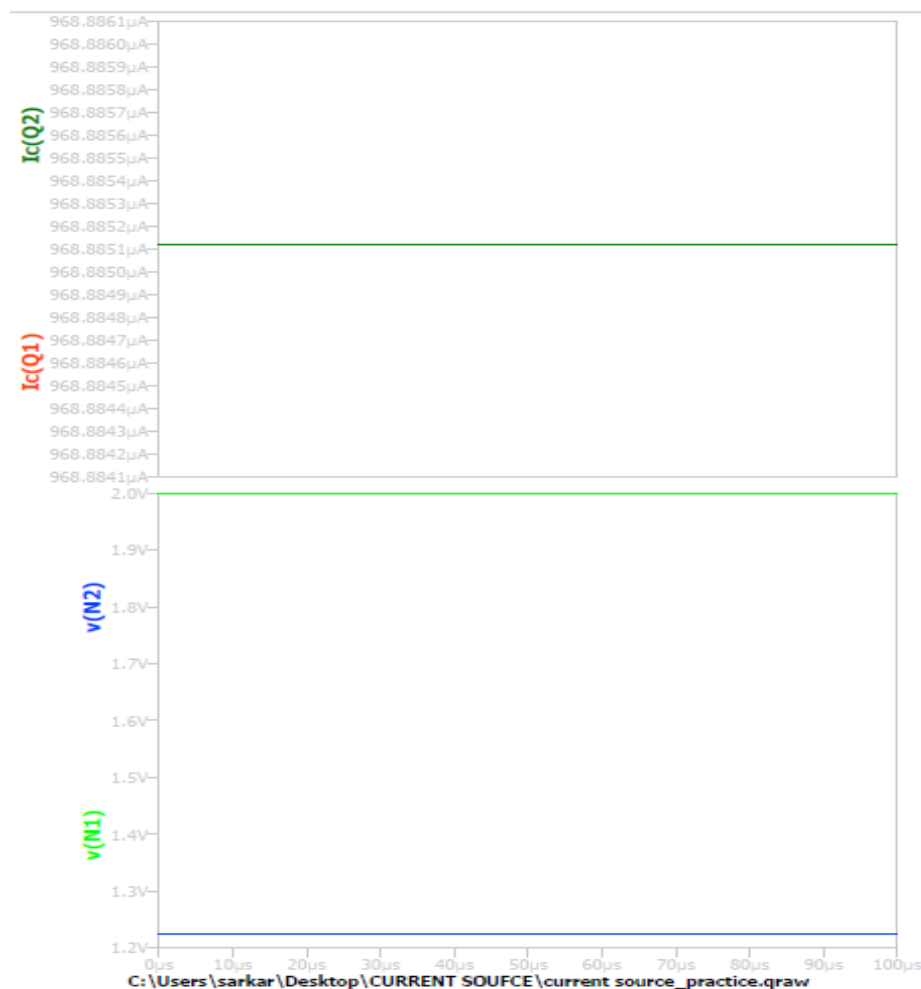


Figure 3: Simulation Result

## 5. Conclusion

In this paper, we have shown a new circuit technique for the compensation of base current in bipolar current mirror circuit. In bipolar CMC we compensate the base current using a Darlington pair

configuration with the basic CMC. This improves the output terminal current mirror to input terminal current. It draws or sinks negligible current from input terminal ( $\frac{I_{ref}}{\beta}$ ) and we can neglect and found  $I_{ref} = I_{out}$ . The output resistance of the circuit is improved by using the Widlar technique, which provides the additional required resistance at the emitter of the output transistor.

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