BJT Current Mirror using BC547B Transistors

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AIM

AIM: To design and analyze a basic BJT current mirror circuit and observe the current-mirroring effect.

***Abstract*—This experiment's goal is to design and analyze a basic BJT current mirror circuit using two BC547B transistors. The circuit shows how two transistors can mirror each other's current flow by utilizing their complimentary characteristics. By placing one transistor in a diode-connected configuration and applying the identical base-emitter voltage to both transistors, this is achieved. By measuring and contrasting the mirrored current with the reference current, the successful operation is then verified.**

***Index Terms*—BJT Current Mirror, BC547B Transistor, Analog Circuit Design, Current Mirroring, Diode-Connected Transistor, Reference Current, Output Current, Active Region, Biasing Circuit, Constant Current Source**

I. Introduction

A basic analog building block called a current mirror is used to "mirror" or duplicate a reference current from one branch of a circuit to another. Because it keeps the output current almost constant regardless of the resistance of the load, it is very helpful in the design of analog circuits. The BC547B NPN transistors, a type of bipolar junction transistor (BJT), are used in this experiment to create a simple current mirror.

Using two closely matched transistors, the current mirror's basic concept is to use one transistor to create a reference current by shorting its base and collector, which turns it into a diode. The second transistor receives the base-emitter voltage (VBE), which is determined by this current. A collector current that nearly resembles the reference current will be produced by the second transistor if both are identical and functioning in the active region.

Analog integrated circuits (ICs) frequently use current reflectors for the following reasons:

- To supply amplifier stages with steady bias currents.
- Increasing gain by acting as active loads
- Ensuring current matching in differential amplifier circuits
- Replicating current in digital-to-analog converters (DACs) and operational amplifiers

This experiment helps in understanding the practical construction and behavior of a BJT current mirror, and how real-world factors like transistor mismatches and temperature variations affect its performance.

II. Theory and Working Principle of Current Mirror

A BJT Current Mirror relies on matching two transistors and applying the same base-emitter voltage to both:

- **Q1** is configured as a diode (**base = collector**).
- **Q2** receives the same base voltage, so it should ideally draw the same current if both transistors are matched.

The reference current is given by:

$$\boldsymbol{I}_{\text{REF}} = \frac{\boldsymbol{V_{CC} - V_{BE}}}{\boldsymbol{R}}$$

Where:

- $\boldsymbol{V_{BE}}$ is the base-emitter voltage (approximately 0.7V for silicon BJTs),
- $\boldsymbol{R}$ is the bias resistor,
- $\boldsymbol{V_{CC}}$ is the supply voltage.

Since both transistors have the same $\boldsymbol{V_{BE}}$, the output current $\boldsymbol{I}_{\text{OUT}}$ ideally mirrors the input current $\boldsymbol{I}_{\text{REF}}$, assuming the transistors are in the active region and thermally matched.

III. Theory and Working Principle of Half Current Mirror

The half current mirror is a variation of the conventional BJT current mirror, designed to replicate a reference current across multiple output branches. It employs three matched NPN transistors (typically BC547B): Q1, Q2, and Q3.

Transistor Q1 is diode-connected (i.e., its base and collector are shorted), and it sets the reference current, I_{REF}. The base-emitter voltage V_{BE} established across Q1 is also applied to Q2 and Q3 due to the shared base and emitter connections. If all transistors are identical and operate in the active region, they exhibit the same collector current:

$$I_{\text{REF}} = \frac{V_{\text{CC}} - V_{BE}}{R_1} \tag{1}$$

In a standard half-current mirror:

- Transistor Q1 is set up with its base and collector shorted together, forming a diode-connected configuration.
- A resistor R connects the emitter of Q1 to ground, establishing the reference current.
- The base of the output transistor, Q2, is also linked to the base of Q1.
- Q2's collector is used as the output node, and its emitter is grounded.

IV. Experimental Methodology

A. Materials and Equipment

- BC547B Transistor(2)
- Digital Multimeter
- Resistors(1k-ohm)
- DC Power Supply(eg-0-12V)
- Breadboard and connecting wires

B. Experimental Procedure for BJT Current Mirror

Circuit Connections:

- Connect the collector and base terminals of Q1 together to form a diode-connected transistor.
- Connect resistor R1 between the 9V power supply (V_{CC}) and the collector of Q1.
- Connect the collector of Q2 to resistor R2, and the other terminal of R2 to V_{CC}.
- Join the bases of Q1 and Q2 together.
- Connect the emitters of both Q1 and Q2 directly to ground.

Biasing and Operation:

- Apply 9V across V_{CC} and ground.
- The diode-connected Q1 establishes a reference current I_{REF} through R1.
- The base-emitter voltage V_{BE} generated by Q1 is applied to Q2, allowing it to mirror the reference current.

Measurements:

- Measure the current through R1 to calculate I_{REF} using Ohm's Law:
$$I_{REF} = \frac{V_{CC} - V_{BE}}{R_1}$$
- Measure the current through R2 (collector current of Q2), which ideally should match I_{REF}.
- Compare the reference and mirrored currents to assess the accuracy of current mirroring.

C. Experimental Procedure for Half Current Mirror

Circuit Connections:

- Connect Q1 in a diode configuration (collector tied to base).
- Connect R1 between V_{CC} and the collector of Q1.
- Tie the bases and emitters of Q1, Q2, and Q3 together.
- Connect R2 between V_{CC} and the collector of Q2.
- The collector of Q3 serves as an additional mirrored current output.

Biasing and Measurements:

- Apply 9V DC to the circuit.
- Measure the reference current I_{REF} through R1.
- Measure the output currents I_{OUT1} (Q2) and I_{OUT2} (Q3).
- Compare the mirrored currents with the reference current to evaluate the performance.

Results and Inference

Current Mirror Circuit

Simulation Results: The simulation of the current mirror circuit was carried out using LTspice. The currents through the resistors R_1 (reference branch) and R_2 (output branch) were observed over time. The simulation graph indicates:

- Current through R_1: $I(R1) \approx 8.17\,\text{mA}$
- Current through R_2: $I(R2) \approx 8.01\,\text{mA}$

This small difference is within acceptable limits and is due to the Early effect and slight mismatches in transistor parameters. The voltages across both resistors are nearly constant, indicating that the current mirror is operating in its active region.

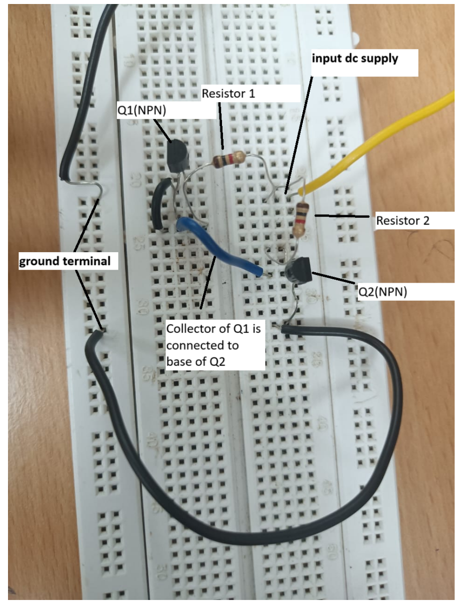

Fig. 1: Connections on breadboard for Current Mirror Circuit

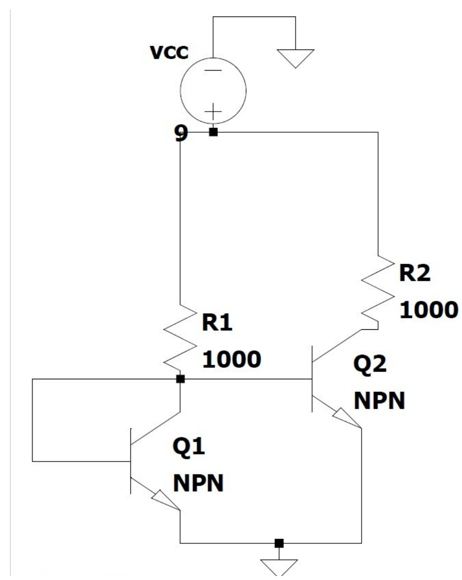

Fig. 2: CURRENT MIRROR CIRCUIT

Experimental Results: The current mirror circuit was built on a breadboard using BC547B NPN transistors and measured using a digital multimeter.

The measured values are:

- Current through R_1 (reference branch): $I(R1) = 7.97\,\text{mA}$
- Current through R_2 (output branch): $I(R2) = 7.96\,\text{mA}$

The experimental results closely match the simulation, confirming that the current mirror effectively replicates the reference current in the output branch.

Half Current Mirror Circuit

Simulation Results: The half current mirror was also simulated using LTspice. The circuit was configured to split the

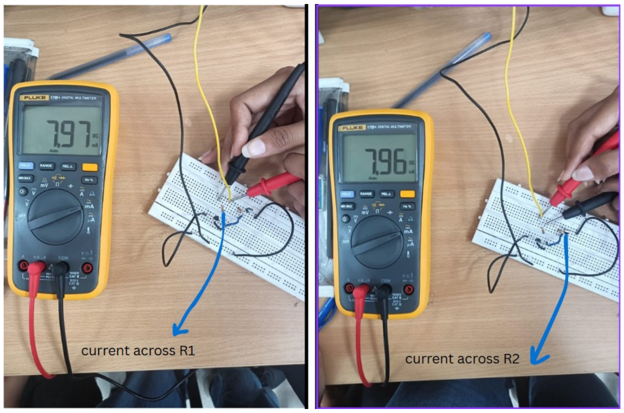

Fig. 3: Measured current through R_1 and R_2 in current mirror setup

reference current between two matched transistors. The results observed were:

- Reference current through R_1: $I(R1) \approx 8.2\,\text{mA}$
- Output current through collector of Q_2: $I_{C(Q2)} \approx 4.6\,\text{mA}$
- Current through Q_3 (second output): $I_{C(Q3)} \approx 4.6\,\text{mA}$

The outputs confirm the half current mirror configuration—both transistors Q_2 and Q_3 draw approximately half of the reference current. This demonstrates current division and load sharing capabilities.

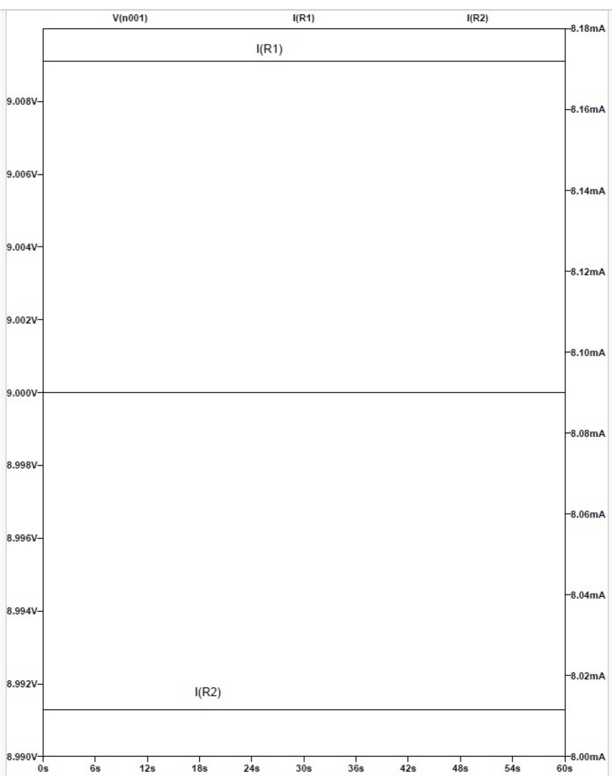

Fig. 4: Simulation result of current mirror circuit

Inference

- Current Mirror: The close agreement between $I(R1)$ and

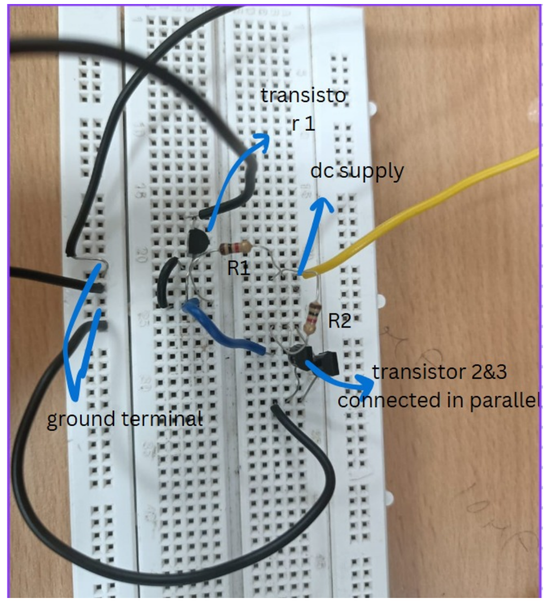

Fig. 5: Connections on breadboard for Half Current Mirror Circuit

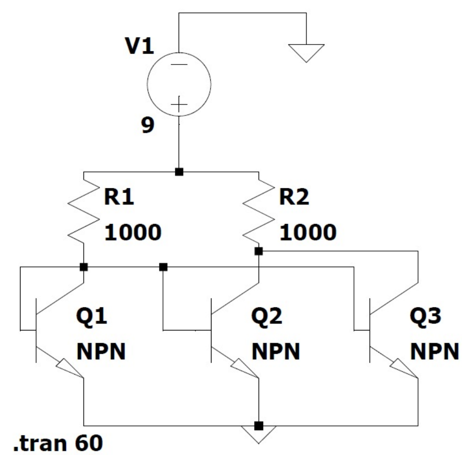

Fig. 6: HALF CURRENT MIRROR CIRCUIT

$I(R2)$ in both simulation and practical setups confirms that the current mirror effectively replicates the reference current at the output.
- Half Current Mirror: The half current mirror distributes the reference current evenly among the output transistors, as expected. The simulation data validates the concept of current division using symmetrical transistor design.
- **Accuracy:** Minor discrepancies (less than 0.2 mA) are likely due to:
  - Variation in transistor β (current gain)
  - Contact resistance and wiring on the breadboard
  - Multimeter measurement precision
- **Conclusion:** Both the current mirror and half current

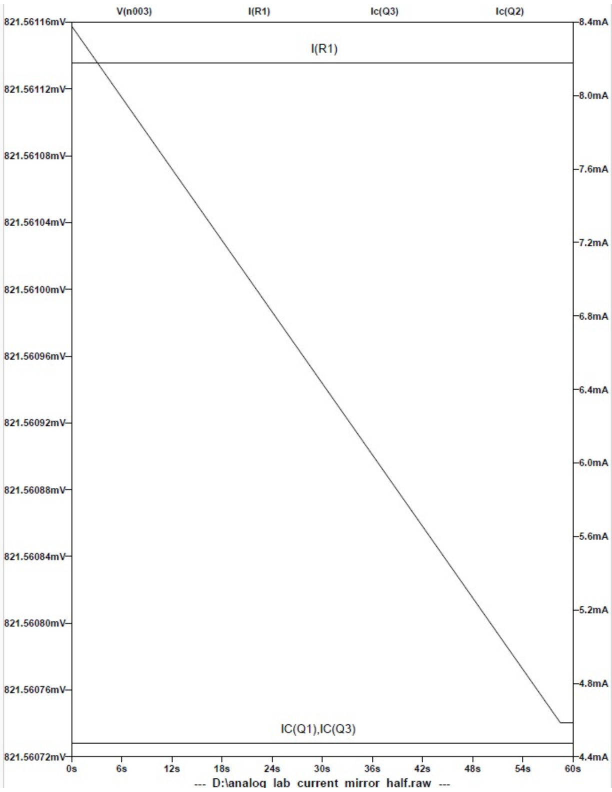

Fig. 7: Simulation result of half current mirror circuit

mirror circuits demonstrate expected functionality. These circuits form the foundation for analog biasing and current sourcing in integrated circuits.

Conclusion and Implications

1. Purpose Recap

The objective of this experiment was to evaluate the performance of a Current Mirror and a Half Current Mirror using BC547B BJTs, by comparing simulated results with practical measurements.

2. Key Observations

- **Current Mirror:** Simulated currents were approximately 8.17 mA (reference) and 8.01 mA (output), while practical values were 7.97 mA and 7.96 mA respectively.
- **Half Current Mirror:** Simulation showed input current of 8.2 mA split equally into two branches of about 4.6 mA each.

3. Conclusion

The current mirror successfully mirrored the reference current with negligible variation, and the half current mirror accurately divided the input current between its outputs. These observations confirm the correct functionality and theoretical behavior of both circuits.

4. Implications in Circuit Design

- Current mirrors are widely used in analog ICs for biasing and signal processing.
- Half current mirrors are useful where precise current division is needed, such as differential pairs and current references.

5. Possible Sources of Error

- Transistor mismatches due to manufacturing tolerances.
- Contact resistance and layout parasitics on the breadboard.
- Measurement inaccuracies due to meter tolerance and thermal drift.

6. Design Considerations

- Use matched transistor pairs for better current accuracy.
- Include emitter resistors to reduce mismatch sensitivity.
- Use PCBs to reduce parasitics in high-frequency or precision designs.

V. Acknowledgments

We extend our sincere appreciation to the instructional team of the EE211 laboratory course at IIT Mandi for their guidance and technical support throughout this experimental investigation.

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