1 Current Mirror - Current Source

1.1 Objective

- To get familiar with the lab equipments while performing the experiment.
- To familiarize the student with the practical aspects and the applications of the current mirror/current source.

1.2 Description

Parameters sensitivity to the variation in temperature is considered the main biasing problem in transistor circuits. To overcome this problem in the discrete BJT circuits a large $R_E$ (consider CE configuration) was found to improve the thermal insensitivity and improve the drift of the operating point as the transistor parameters change with temperature. In CE amplifiers a single current source is used to replace the $R_E$ as shown in figure (1). Besides taking advantage of the high output resistance of the current source, it maintains $I_E$ constant.

![Figure 1](image_url)

In the integrated circuits IC, a large number of amplifiers are internally connected and placed on a single semiconductor wafer. Each amplifier stage or electronic circuit is connected internally to a biasing circuit in order to establish a desired operating characteristic. The trend in IC fabrication is to use a building block or cell to build a variety of electronic circuits. In some BJT integrated circuits the basic block may contain a small resistor and junction capacitors. The fabrication of the large resistors or large capacitors is almost impossible economically. The biasing in IC design is based on the use of the current...
sources instead of the large resistors. Another circuit element such as diodes can be implemented using the same building block. The basic building block is the transistor itself. Figure (2) shows the basic current mirror and the current source. They are consisting of two matched transistors $Q1$ and $Q2$ with their bases and emitters connected together. The transistor $Q1$ in both circuits is transformed into a diode by short-circuiting the collector and the base.

![Figure 2](image_url)

The current mirror is fed with a constant reference current $I_{REF}$, and the output current is taken from the collector of $Q2$. The transistor $Q2$ must kept active all the time by keeping its collector voltage higher than that of the base. In the current source circuit, reference current to the mirror $I_{REF}$ is determined by a resistor $R$ which is connected to the positive power supply $V_{CC}$. The current $I_{REF}$ is given by

$$I_{REF} = \frac{V_{CC} - V_{BE}}{R} \approx \frac{V_{CC} - 0.7}{R}$$

Consider the following assumptions for current source and current mirror:

- The two transistors are perfectly matched
- Finite $\beta$ and Early effects are neglected.

Then the output mirror current in this case will be equal to the input reference current $I_O = I_{REF}$.
The circuits will operate as a constant current source and current mirror as long as \( Q2 \) remains in the active region, or \( V_{CE} \geq V_{BE} \). The characteristics and the behavior of the current mirror will be determined according to the followings:

- Current gain accuracy.
- Output resistance.
- Minimum output voltage.
- Input current range.
- Frequency response.

**Current – Gain Accuracy and Output Resistance**

The current gain is the ratio of the output current to the input current \( (I_o/I_{REF}) \). For ideal current mirror, with identical transistors, the current gain is unity (neglecting the Early effect). The practical current mirror has a ratio close to unity. The current gain accuracy and output resistance for the simple current mirror shown in figure 2 is given in the table below for \( \beta=100 \) and \( r_o = 80K\Omega \).

<table>
<thead>
<tr>
<th>Current mirror</th>
<th>Current gain ( \frac{1}{1 + 2/\beta} = 0.9803 )</th>
<th>Output resistance ( r_o = 80K\Omega )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As mentioned earlier, large resistors cannot be fabricated on a chip. An alternative solution is the usage of the current source to replace the large resistors. This is known as a dynamic or active load. The output resistance of the current source is used in place of the desired large collector resistance as shown in the figure 3.

![Figure 3](image)

a) Current mirror is used as an active load

**Figure 3**

All transistors we will refer to in the procedure section are taken from a well-matched pair transistors fabricated on a single substrate. The chip, which hosts these transistors, is called transistor array. The CA3046 transistor array consists of
five transistors. **NOTE THAT** pin #13, the substrate must be connected to the –V supply or the ground. The pinout is given below.

![Pinout Diagram](image)

**Figure 4**

1.3 **Experiment Equipments**

- KL-21001 main experiment unit
- Multimeter
- CA 3046 Transistor Array
- Resistor (100k)
1.4 Procedure

1. Build the circuit shown in figure above and calculate $I_{REF}$.

$I_{REF} = \underline{\phantom{000}}$

2. By varying $V_2$, fill the appropriate values in the table

<table>
<thead>
<tr>
<th>$V_{CE} (V2)$</th>
<th>3V</th>
<th>6V</th>
<th>9V</th>
<th>12V</th>
<th>15V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Calculate $r_0$

$r_0 = \underline{\phantom{000}}$

4. Calculate $V_A$ (Early Voltage)

$V_A = \underline{\phantom{000}}$

5. Adjust $V_2$ to 18V and connect a variable resistance (1M) in series with ammeter.

Find the maximum value of the resistor for the active region.

$R_{max} = \underline{\phantom{000}}$