McGill

Microelectronics ECSE 335

Laboratory No. 1

Design and Verification of a Voltage and Current Reference Circuit

Purpose:

Investigate the operation of a voltage and current reference circuit through a transistor-level simulator. Use any one of the many freely-available SPICE tools such as PSPICE, LTSPICE or TINA-TI.

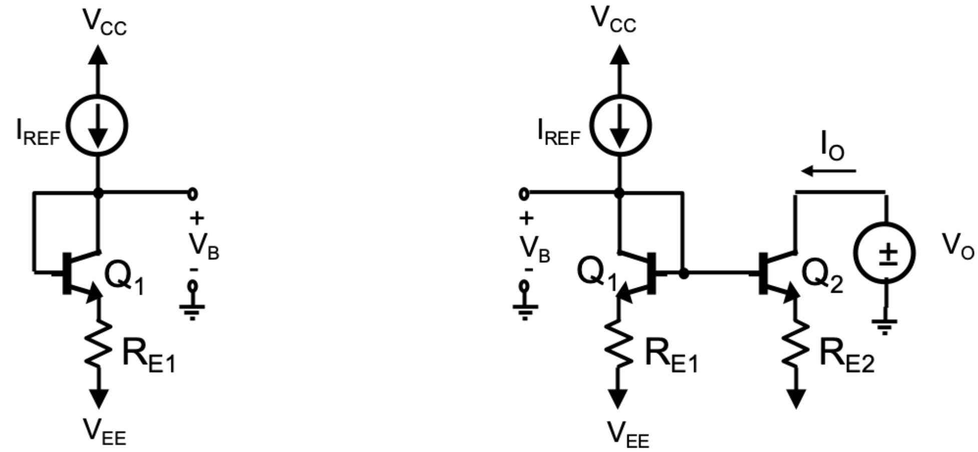
Equipment Required:

a. Computer
b. SPICE Simulator (student choice)

Voltage and Current Reference Circuits

In addition to a circuit that supplied power to operate an electronic circuit and its intended load, voltage and current references provide little, if any significant power, but are used as reference points in an electronic circuit for biasing and/or algorithmic control. Figure 1.1 display a votlage and current reference circuit constructed from an npn transistor. The most fundamental voltage reference circuit involves a diode-connected transistor Q_1 as shown in Fig. 1.1(a) connected in series with a resistor R_E and fed with a constant current I_{REF} to produce an out voltage V_B. The student may wonder why the diode-connected transistor Q_1 is used at all, if an ideal current source is available. In practice, the current source would be replaced by a resistor or another transistor element. Throughout this class, a resistor will be used to create this bias current level. The value of the resistor is chosen according to the desired output voltage level V_B according to

$$R_{REF} = \frac{V_{CC} - V_B}{I_{REF}} \tag{1}$$



(a) (b)

Figure 1.1: Voltage and current reference circuits using npn transistor: (a) voltage reference circuit, and (b) current reference circuit.

The current reference circuit shown in Fig. 1.1(b) consists of a voltage reference circuit involving Q_1 and another transistor designated as Q_2 with a resistor $R_{E,2}$ in series with its emitter terminal. As is self-evident, the based of Q_2 is driven by the voltage level created by the reference voltage circuit involving Q_1. The output of the current reference is derived as the collector current of Q_2, assuming this node is held at some bias voltage V_O. Together, Q_1 and Q_2 with emitter resistors R_{E1} and R_{E2} form what has come to be known as the *Widlar current mirror* in generalized form in honor of its inventor, Robert Widlar, a pioneer in analog IC design. As a first order approximation, the interrelationship between the reference and output currents can be written as

$$I_{REF}R_{E1} - I_O R_{E2} = V_T \ln\left(\frac{I_O}{I_{REF}}\right) \quad (1)$$

where V_T is the thermal voltage. This particular current reference circuit is known to have excellent termperature characteristics and is widely used in bipolar circuits.

Write-Up Requirements:

A good laboratory report should contain a **brief** description of what the experiment was about, including circuit diagrams, and what you did, your data, your results, and anything else called for in the assignment, such as questions inserted in the laboratory description. Answers to these questions require observations that need to be made at the time you do the experiment.

The laboratory report should be written using the IEEE paper style consisting of a **double-column single-space format**, and must adhere to the following when necessary:

1. Title page - Title of the assignment/project, authors' name, and course name.
2. Abstract - Abstract of the assignment/project report.
3. Introduction
4. Main body of the assignment/project report including figures.
6. Conclusions
7. References
8. Appendices

Preparation/Experiment

This experiment does not involve any bench work involving physical instruments and equipment. Rather, this exercise is meant to explore your design choices and its impact on the operation of a circuit using a simulator. In your report, please include all design details together with simulation results supporting your conclusions as described below.

Voltage Reference Circuit

1. Design the voltage reference circuit shown in Fig. 1.1(a) to produce an output voltage level of 1.5 V. Use an ideal current source of 1 mA and a power supply of ±5 V. Assume that the transistor is of the npn MPS3704 commerical type. Compute the DC node coltages of the circuit and confirm that the output is indeed at your desired value? Provide all component values in your write up.

2. Replace the ideal current source with a resistor interconnecting V_{CC} and collector terminal of Q_1. Compute the DC node voltages of the circuit and confirm that the output is indeed at your desired value? Provide your evidence in your report.

3. Attached a current source across the output terminal of the voltage reference circuit and ground and pull a current level of 0 mA to 500 μA from the output and plot the output voltage as a function of load current. *Comment on the results that you see.*

4. Run a DC analysis across a temperature change of 0°C to 85°C and observe the output voltage. Compute the temperature coefficient TC across the full change in the output voltage. TC is defined as the largest change in the output voltage over the 85°C temperature change.

Current Reference Circuit

5. Design the current reference circuit shown in Fig. 1.1(b) to produce an output current level of 1 mA at a 3-V level. Use an ideal current source of 1 mA and a power supply of ±5 V. Assume

that the transistor is of the npn 2N2222A commerical type. Compute the DC node voltages and currents, and confirm that the output current is indeed at your desired value? Provide all component values in your write up.

6. Replace the ideal current source of 1 mA with a resistor interconnecting V_{CC} and collector terminal of Q_1. Compute the DC node voltages of the circuit and observe the output current. Is the current exactly equal to the desired current level? *Please provide comments in your report.*

7. A method to compenste for base current is to add a transistor in the base path of the diode-connected transistor. Arrange the circuit of Fig. 1.1(b) to include base-current compensation. What output current results?

8. Run a DC analysis across a temperature change of 0°C to 85°C and observe the output current. Compute the temperature coefficient TC across the full change in the output voltage.

9. Compute the output resistance of the current mirror. Compare this result with that predicted by a small-signal analysis.

This concludes this lab.