University of California, Davis
Department of Electrical and Computer Engineering

EXPERIMENT No. 4
TRANSISTOR CURRENT SOURCES

I. INTRODUCTION

Transistor current sources are important circuit blocks both for biasing analog circuits such as emitter-coupled pairs and for use as load elements of transistor amplifiers. In this experiment we will explore the simple current source, the Widlar current source, and the cascode current source from the standpoint of output current and output resistance. You should read the first part of Chapter 4 in the text book before starting.

II. BACKGROUND

A simple current source consists of two transistors with their bases and emitters connected (see figure 1). This configuration is often called the current mirror. Since the base-emitter voltage is the same for both transistors, the collector currents will be identical, provided that:

a) the two transistors are "matched"
b) both are forward active (Q1 is always forward active. Why?)
c) $\beta_F >> 1$
d) V_A large

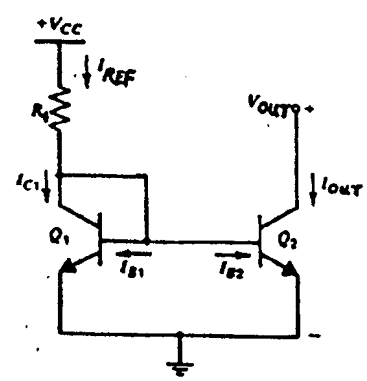

Figure 1. Simple current source

The collector current of Q2 (I_{OUT}) will match that of Q1 (I_{C1}), provided that all the previous conditions have been met.
A plot of I_{OUT} versus V_{OUT} of transistor Q2 is shown in figure 2.

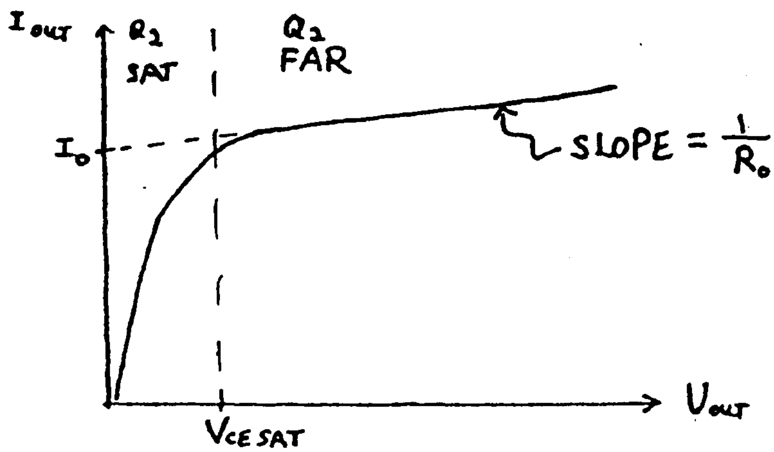

Figure 2. I_{OUT} versus V_{OUT}

Figure 2 shows that as V_{OUT} increases above $V_{CE\ SAT}$, transistor Q2 enters the forward active region. When in this region, transistor Q2 can be modeled as a current source in parallel with a resistance R_O (figure 3):

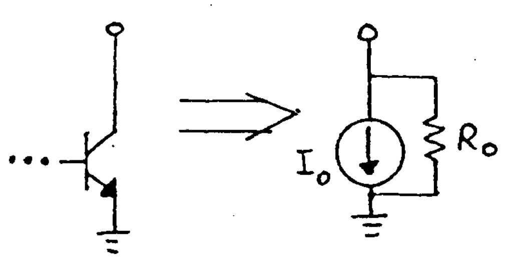

Figure 3. Equivalent model of current source

where $1/R_O$ is the slope of the I_{OUT} vs. V_{OUT} curve in the forward active region , and I_O is the Y-intercept when this curve is extended.(fig. 2).

III. SIMPLE CURRENT SOURCE

Design a simple current source to realize a current output of 100μA, with Vcc=10 volts. Use your calculated value for R_1 and build the following circuit.

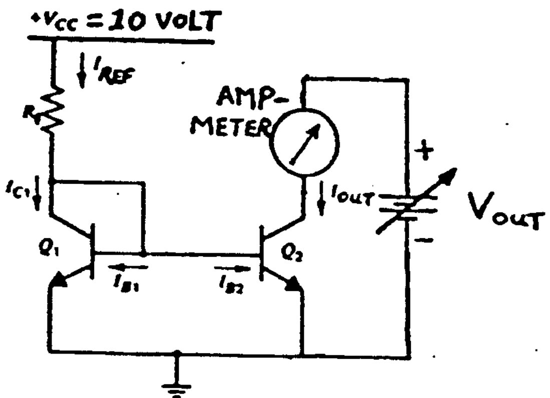

Figure 4. Simple current source

Now measure the output current as a function of V_{OUT} from 0 to 0.5 volts in 0.1 volt steps, and from 0.5 to 10 volts in 0.5 steps. From this data, plot I_{OUT} vs. V_{OUT} and determine the equivalent I_O, R_O (see figure 3) and the equivalent open circuit voltage V_{Thev} for the current source ($V_{THEV} = I_O R_O$).

IV. MULTIPLE CURRENT SOURCES

Two (or more) current sources can be built by "chaining" more transistors to the basic configuration of figure 4. Build a second current source by adding transistors Q4 & Q5 to the circuit built in part III (see figure 5). Be sure to tie the unused collector of Q2 to V_{CC} so that Q2 will not saturate and I_{B2} will remain small.

Again, measure the output current I_{OUT} as V_{OUT} varies between 0 and 10 volts. Determine the equivalent I_O, R_O, & V_{Thev}. Compare these values with the values obtained from part III. How are they different or similar? Why?

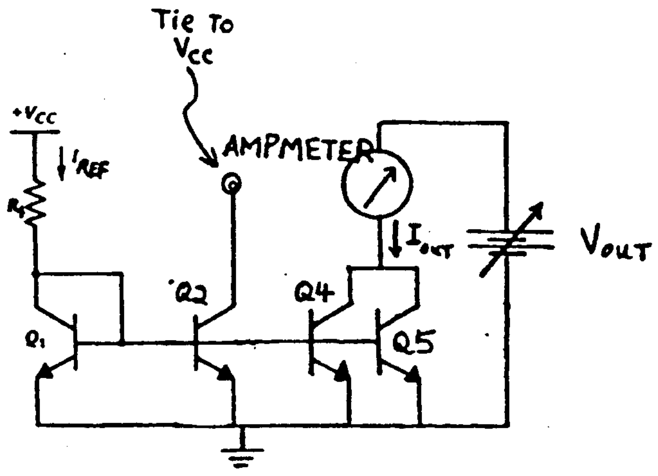

Figure 5. Multiple current sources

V. WIDLAR CURRENT SOURCES

Using the Widlar circuit shown below (figure 6), design a current source to realize a current output of 10μA, with the same R_1 and V_{CC} as in part III. Measure the output current for V_{OUT}= 1, 5, &10 volts. Determine I_O and R_O. Calculate R_O using small-signal analysis (use data from lab 1 as needed), and compare the calculated and measured values. Notice the high value of R_O.

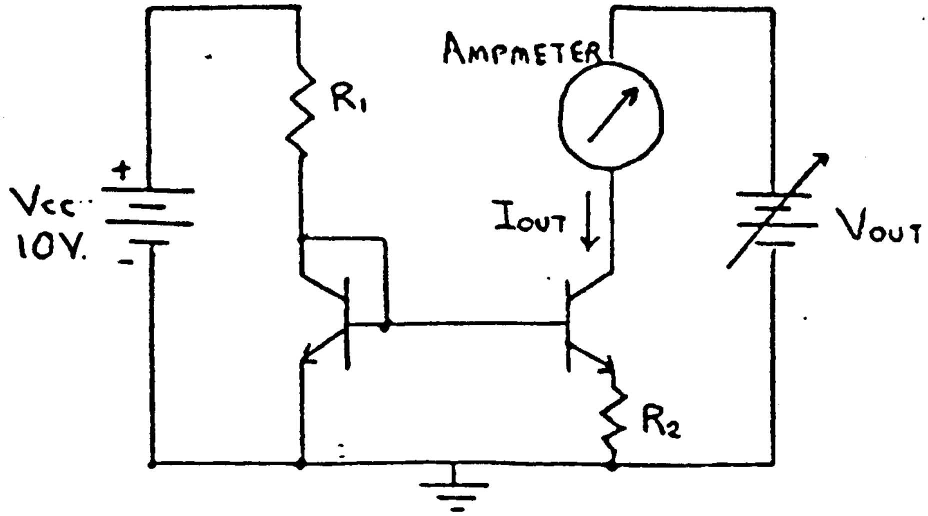

Figure 6. Widlar current source

VI. CASCODE CURRENT SOURCE

Construct the cascode current source shown below (figure 7) using two transistor pairs. Compute $\mathbf{R_O}$ and $\mathbf{V_{Thev}}$ by measuring the output current $\mathbf{I_{OUT}}$ for $\mathbf{V_{OUT}}$ = 1 volt & 10 volts. Note that you will be measuring very small changes in current because of the very high output resistance. Calculate $\mathbf{R_O}$ using small-signal analysis (see text, Sec. 4.2.5.1), and compare the calculated and measured values.

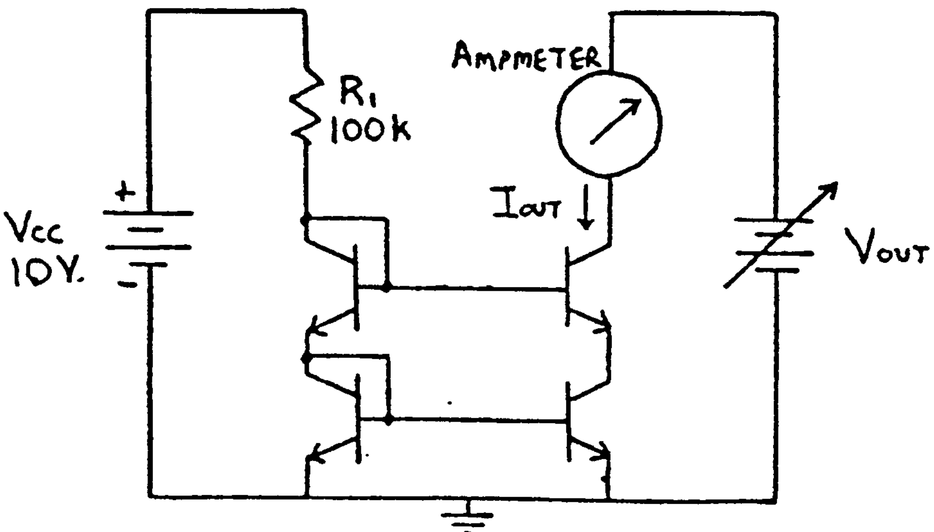

Figure 7. Cascode current source

Lab Results:

Experiment - TRANSISTOR CURRENT SOURCES

III. SIMPLE CURRENT SOURCE

R_1= ________

I_O= ________ R_O= ________ V_{Thev}= ________

IV. MULTIPLE CURRENT SOURCE

I_O= ________ R_O= ________ V_{Thev}= ________

V. WIDLAR CURRENT SOURCE

R_2= ________ I_O= ________

measured R_O= ________ calculated R_O= ________

V_{Thev}= ________

VI. CASCODE CURRENT SOURCE

I_O= ________

measured R_O= ________ calculated R_O= ________

V_{Thev}= ________