Lab Report 4 by Jamie O'Brien, Sabrina Pereira, and Shyheim Russell

1 Introduction

In this lab, we assessed how well four transistors on a chip are matched. We also built and analyzed two translinear circuits.

2 Experiment 1: Bipolar Transistor Matching

In this experiment, we used a MAT14 transistor chip containing four individual transistors. Since in many cases transistors in a circuit need to be matched, we wanted to assess how well the transistors in the chip are matched. We swept the base voltage of each resistor and measured the base and emitter currents. From the two currents, we extracted the base current, given that $I_c = I_e - I_b$. To assess how well the transistors are matched, we wanted to compare their saturation currents, I_s, and current gains, β. When we make as semi-logarithmic of collector current as a function of base voltage, we find the linear fit given by $log(I_c) = log(I_s) + \frac{1}{U_T}V_b$, so by finding a linear fit to the semi-log plot, we can extract I_s. By definition, the current gain can be found using $\beta = \frac{I_c}{I_b}$. The results are given in the following table, showing that the resistors are fairly well matched.

Saturation Current and Current Gain List		
Transistor	$I_s(A)$	β
Q1	3.3770e16	535
Q2	3.3923e16	532
Q3	4.1161e16	533
Q4	3.7362e16	531

When assessing the β values, we approximated β when it was most stable, as it wasn't entirely consistent across I_b and I_c values.

We also wanted to compare the base and collector currents, I_b, I_c, with respect to base voltage, V_b. As shown in Figure 1, the currents of each resistor across V_b values are very consistent. At lower base voltages, there is some discrepancy between base currents, but as base voltage increases, the base currents quickly converge.

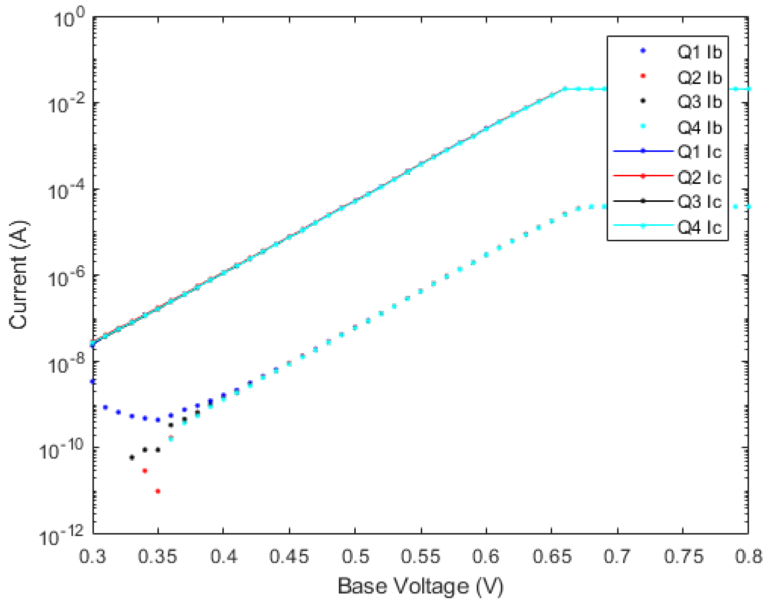

Figure 1: Base Current, I_b, and Collector Current, I_c, with respect to Base Voltage V_b.

To further analyze how similar the collector currents are, we solved for and plotted each transistors difference in collector current from the average collector current across the four transistors. As seen in Figure 2, at very small current values, the collector currents vary a bit but never exceed 15% in either direction, and converge around $0.7A$ as we saw before.

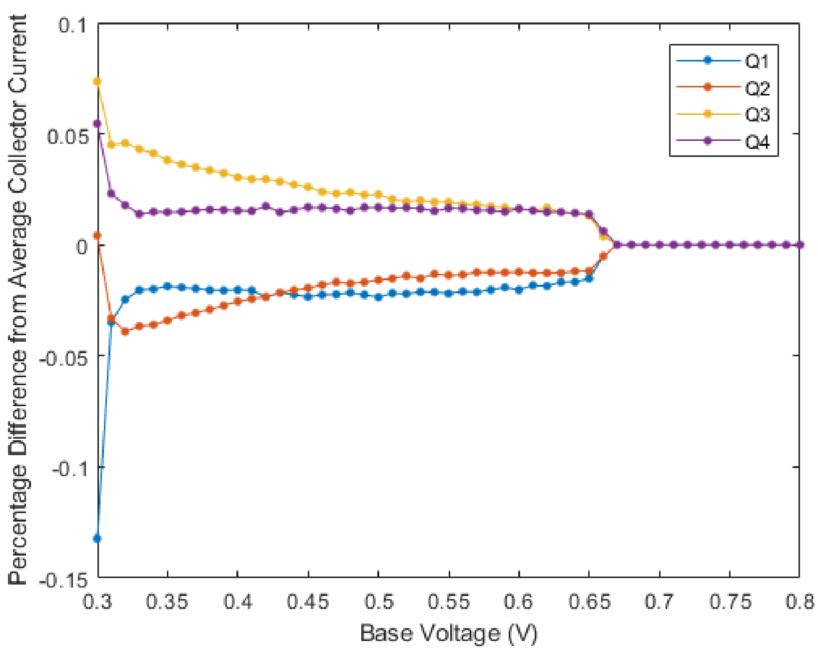

Figure 2: Percent collector current difference from average collector current

We also looked at the current gain, β, with respect to base current, as shown in Figure 3. The gain values are a bit inconsistent with very small currents, but as current becomes much larger, the gain values converge and become pretty consistent, giving us a current gain of 533, as we previously saw in our table.

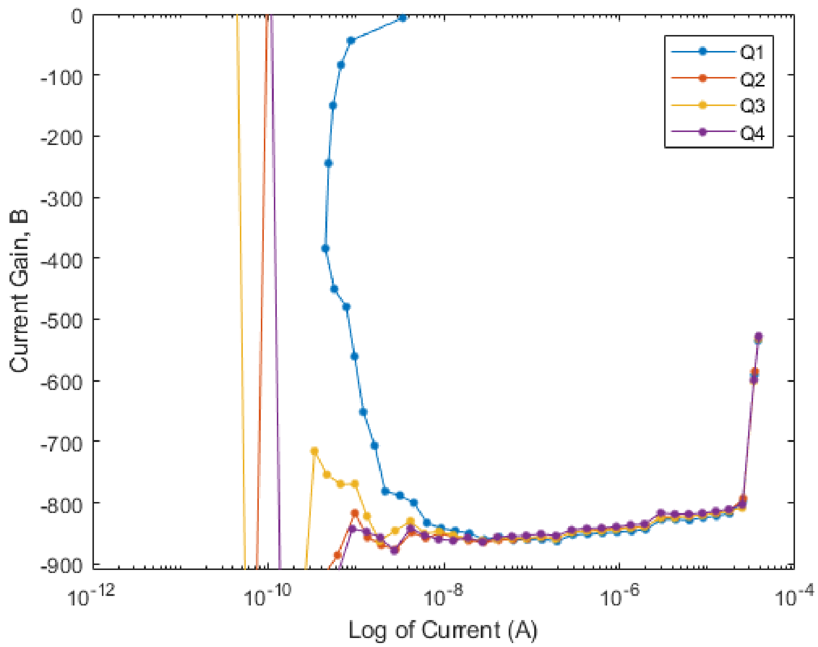

Figure 3: Current gain, β, with respect to base current, I_b

3 Experiment 2: Translinear Circuit 1

In this experiment, we set up a translinear circuit that consists of four transistors and requires a current sink and a current source, as shown in Figure 4. We used a MAT14 chip for the transistors. Because our SMU only has two channels and we want to measure current and votlage, we needed to supply either the current source or current sink without the SMU. To do this, we used and op-amp to make a current sink, Figure 5, that acted as Iy and a current source, Figure 7 that acted as Ix.

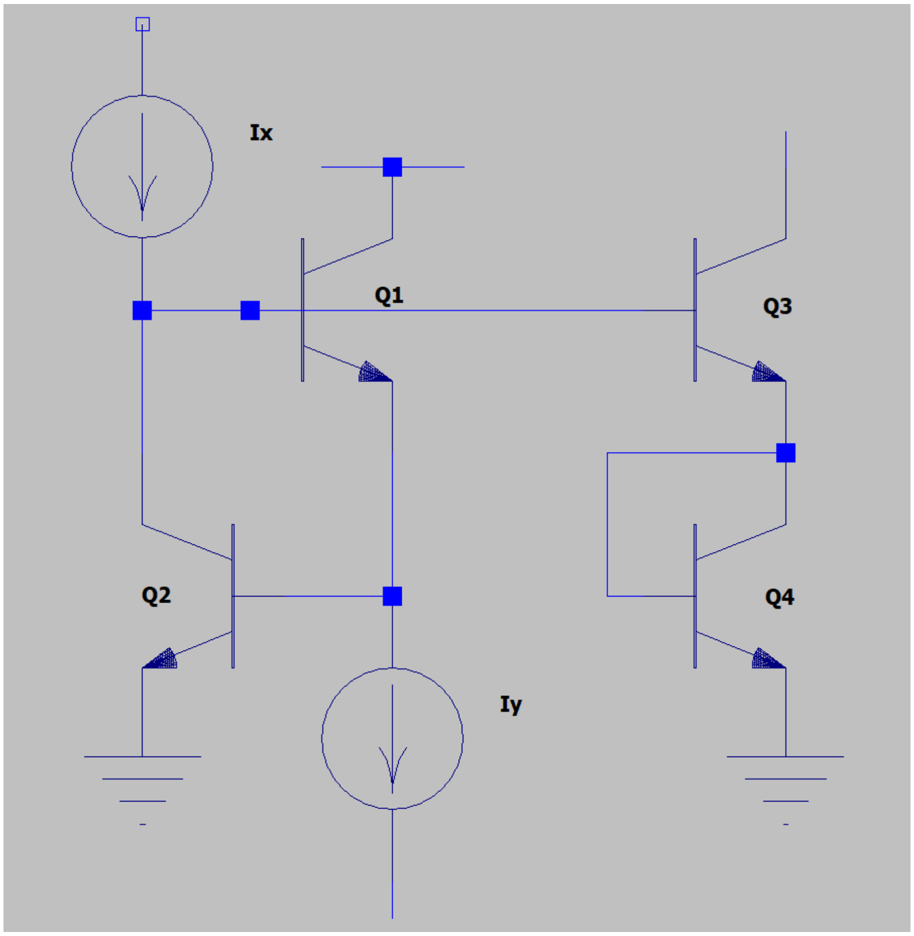

Figure 4: Translinear Circuit 1

For the first part of the experiment, we built the following current sink:

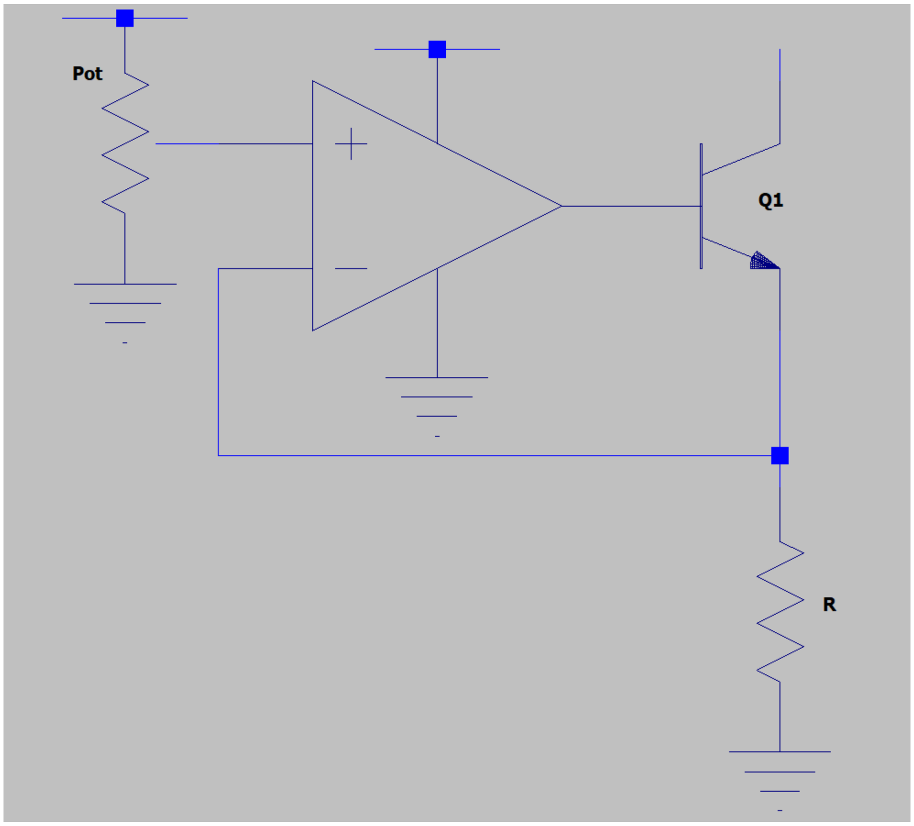

Figure 5: Current Sink

When we used the current sink to replace I_y, we swept I_x three times, using a different value of I_y for each sweep, as shown in Figure 6. We controlled the value of I_y by setting V_{in} to .25V and changing the resistor values with 250Ω, 2.5kΩ, and 25kΩ resistors. From these results we can see that our experimental data matches closely our theoretical plot. To get our theoretical plot, we used the equation from the prelab: $I_z = \sqrt{I_y * I_x}$.

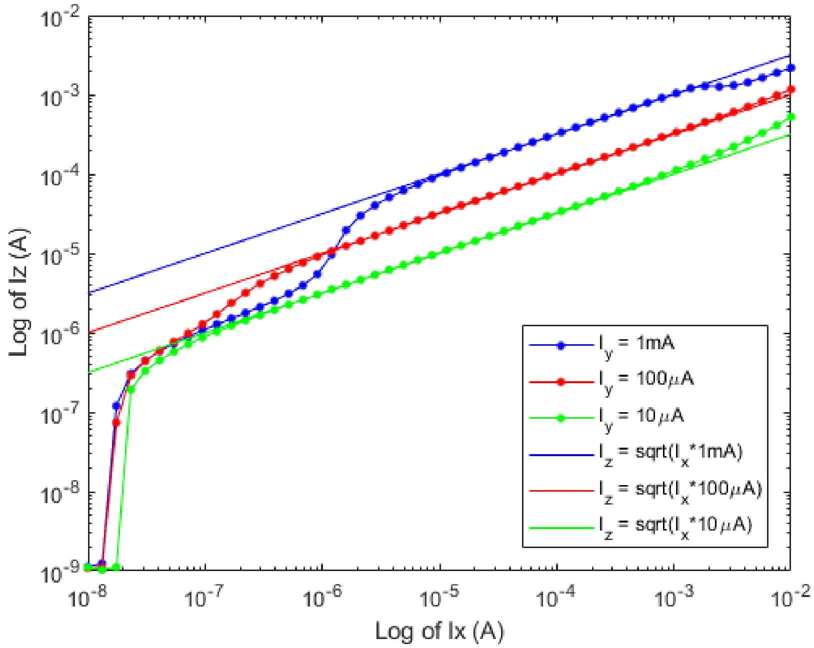

Figure 6: Translinear Circuit 1 Data with the log of I_z is plotted against the log of I_x for the current sink

For the next part of the experiment, we added the following current source to our circuit.

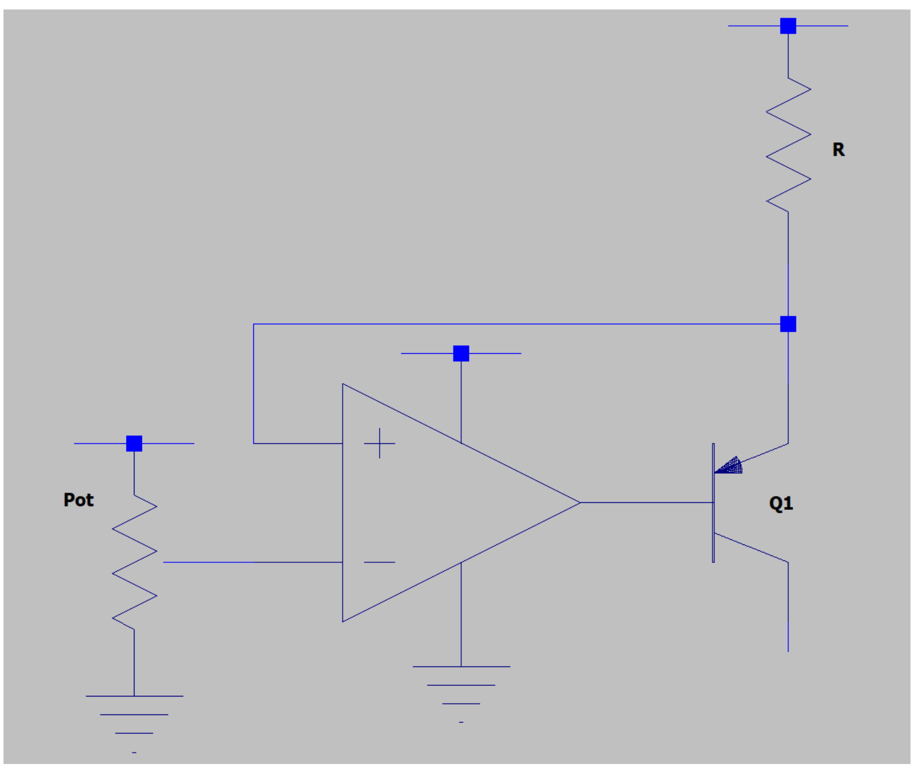

Figure 7: Current Source

We used the current source to replace I_x and swept I_y three times, once for each value of I_x. Again, we controlled the value of I_x by setting V_{in} to 3V and changing the resistor values with 250Ω, 2.5kΩ, and 25.5kΩ resistors. The results of these sweeps can be seen in Figure 8. As shown on the graph, our data matches with our fit quite well.

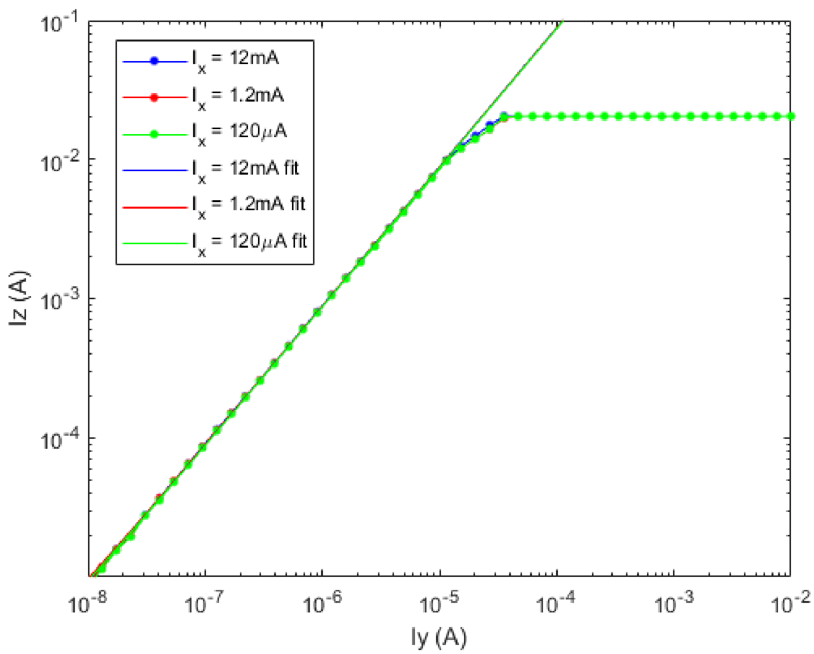

Figure 8: Translinear Circuit 1 Data with the log of I_z is plotted against the log of I_x for the current source

4 Experiment 3: Translinear Circuit 2

In this third experiment, we set up a second translinear circuit, as in Figure 9, that also requires a current source and a current sink. We used the same MAT14 chip for this circuit as well. Our methodology for data collection was the same as it was for the first translinear circuit: replace I_y with a current sink, sweep I_x three times with a different value of I_y for each, then replace I_x with a current source, sweep I_y three times with a different value of I_x for each. To get the theoretical plots, we used the equation from the prelab: $I_z = \frac{I_x^2}{I_y}$.

These results can be seen in Figure 10, the one connected to the current sink, and Figure 11, the circuit connected to the current source.

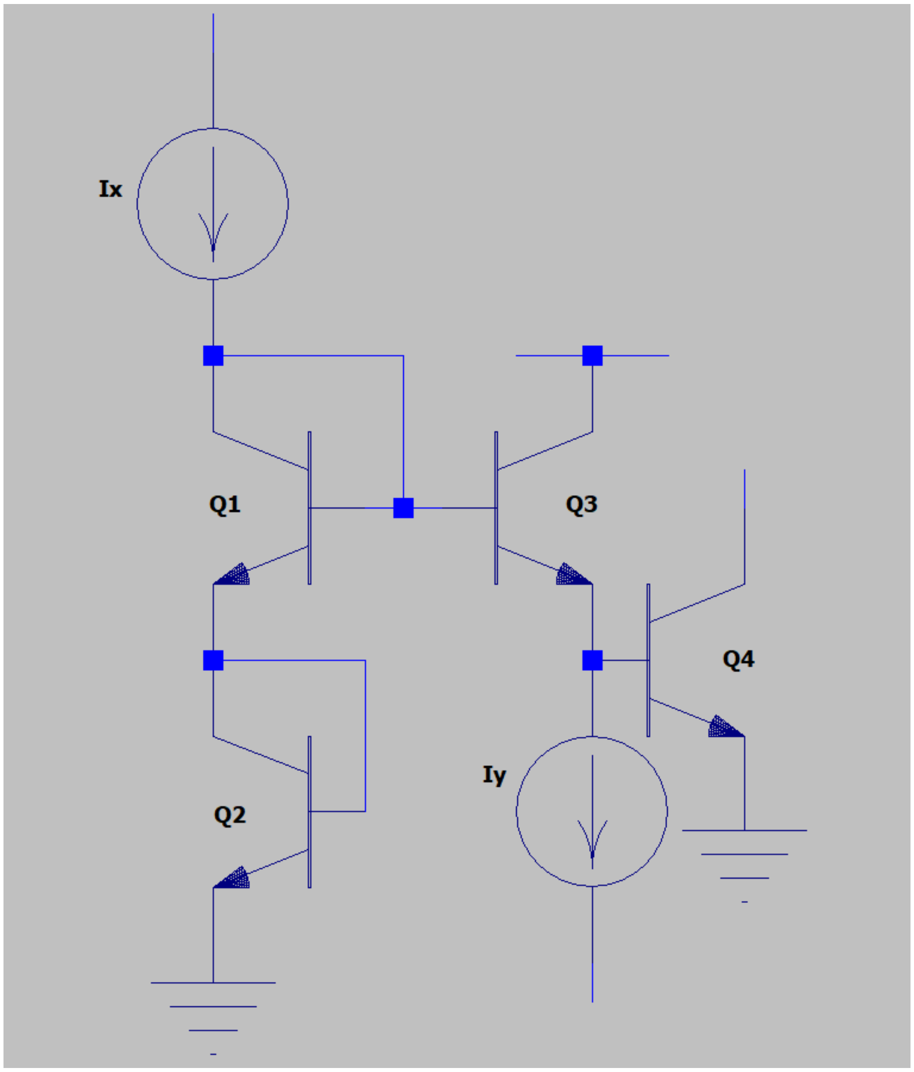

Figure 9: Translinear Circuit 2

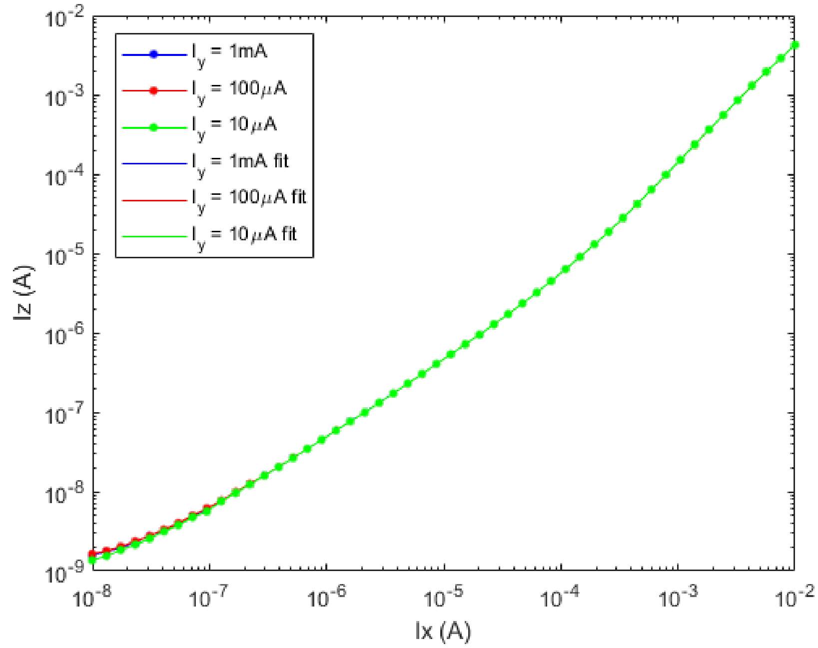

Figure 10: Translinear Circuit 2 connected to Current Sink

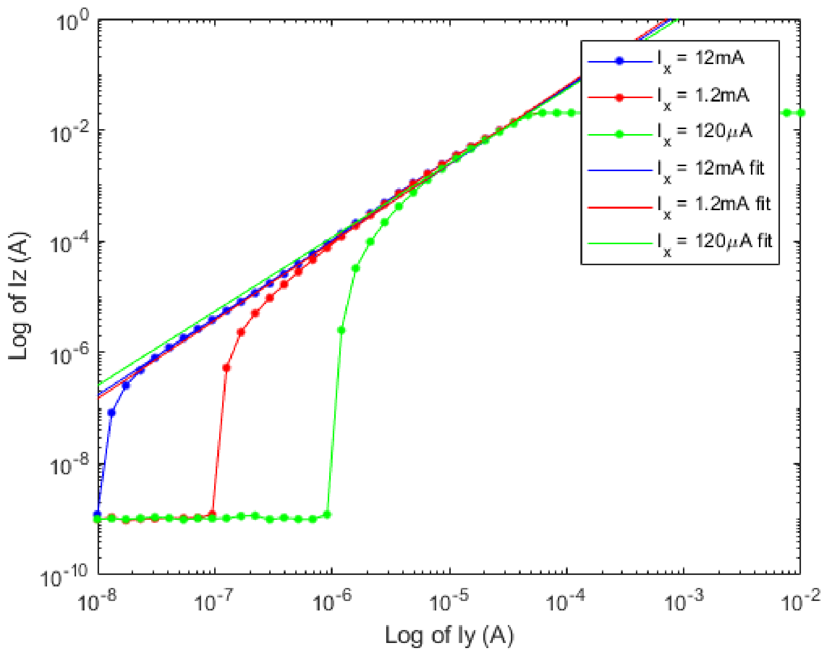

Figure 11: Translinear Circuit 2 connected to the Current Source