EEE381 Tech Memo

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Subject: Lab #03

1 Abstract

The purpose of this exercise was to build two current sources, one simple current source using two transistors and the other a modified Wilson current source, using four transistors and to observe and analyze the differences between them.

2 Theory

MOSFETs can be used to make a current source to supply a certain amount of current to a cicuit. In this exercies two different current sources were built and compared. The first was a simple current source using two transistors. The circuit can be seen in Figure 1.

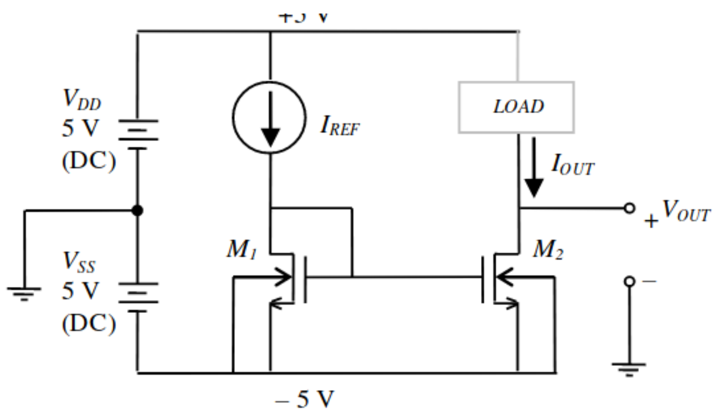

Figure 1: Simple current source

The reference current, I_{ref} is created using a resistor. The current through the resistor depends only on the value of that resistor. This relationship can be seen in Equation 1.

$$R_{ref} = \frac{2V_{DD} - V_{GS}}{I_D} \tag{1}$$

Since the target current for this exercise was 4 mA, R_{ref} can be calculated using V_{DD}, V_{SS}, and the transistor current equation. Using this method, the calculated R_{ref} for 4 mA current was 1637 Ω. It should be noted that because there is no manufactured resistor with this value, the closest value resistor was used, which was 1.5 kΩ.

The second current source that was built was a modified Wilson current source. This source uses four transistors and can be seen in Figure 2.

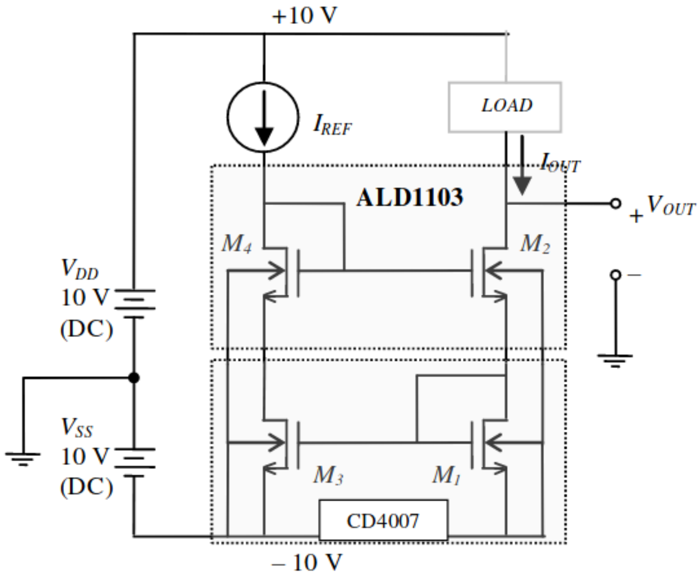

Figure 2: Modified Wilson current source

Just as with the simple current source, I_{ref} is created using a resistor, R_{ref}. The equation for this resistor, however is slightly different due to the fact that there are two voltage drops down to V_{SS} through two transistors. This means that the V_{GS} term must be multiplied by two. This can be seen in Equation 2.

$$R_{ref} = \frac{2V_{DD} - 2V_{GS}}{I_D} \tag{2}$$

Again, using this equation and the transitor current equation, the calculated value of R_{ref} is 3275 Ω. It should be noted that no resistors are manufactured at this value and therefore, the resistor that was actually used was a 3.3 kΩ.

When comparing these two current sources, an important property to look at is the output impedance. The output impedance of the simple current source is simply the output impedance of the transistor, r_o while the output impedance of the Wilson current source is $g_m r_o^2$. This makes the Wilson current source closer to an ideal current source since the output impeadance of an ideal current source is ininity. Using the given properties of the transistors, the R_{out} for the simple current source is 25 kΩ and the R_{out} for the Modified Wilson current source is 2.5 MΩ.

Both the current sources have a maximum load resistatnce that they can drive. If the resistance becomes too large, the current through the load will drop below the reference current due to the transistor falling out of saturation. This can be calculated using the transistor current equations and the conditions for saturation. Table 1 shows the max resistances for each current source.

Table 1: Maximum Load Resistance

Current Source	$R_{L_{max}}(\Omega)$
Simple	1987
Modified Wilson	3900

Both cirucit were simulated using PSPICE to observe the effect that changing the load resistance had on the current through the current source. The data for both the simple and Wilson current source can be seen in Tables 2 and 3.

Table 2: Simple Current Source I_D vs. R_L

R_L (Ω)	I_D(mA)
100	3.78
500	3.75
1000	3.70
1500	3.64
2000	3.55
2500	3.30

Table 3: Wilson Current Source I_D vs. R_L

R_L (Ω)	I_D(mA)
100	3.58
1000	3.56
1500	3.55
2000	3.55
2500	3.54
3000	3.54
3500	3.53
4000	3.49
4500	3.30

Both sets of data show that once R_L exeedes the maximum, I_D starts rapidly decreasing. This shows that the R_{ref} resistor has been correctly chosen.

3 Results and Discussion

Both the simple and Modified Wilsons current source were built and measured in-lab. Different load resistances were used and the corresponding diode current was measured and recorded along with the voltage at the output. The relationship between the transistor current and voltage at the output was then graphed to find the output resistance. Figures 3 and 4 show the V_o vs. I_D relationships and Table 4 shows the experimental R_{out} values.

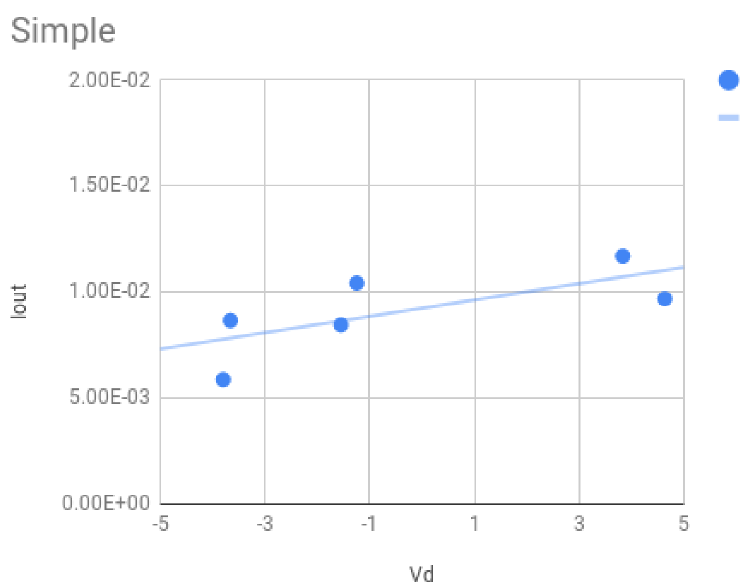

Figure 3: Simple current source V_o vs. I_D

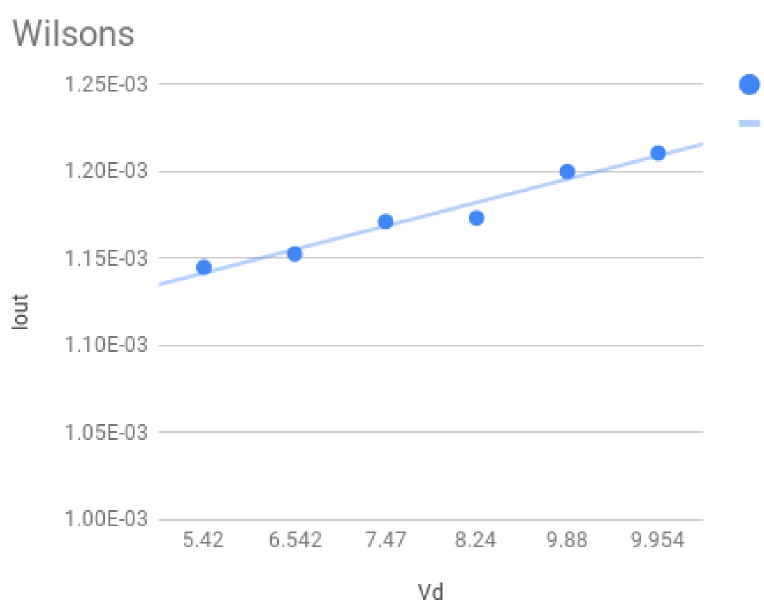

Figure 4: Modified Wilson current source V_o vs. I_D

Table 4: Experimental R_{out}

Current Source	R_{out}
Simple	38.5 kΩ
Wilson	1.3 MΩ

These experimentally found values for R_{out} are relativley close to the values calculated in the

Theory section and again shows that the modified Wilsons current source has a significantly higher output resistance.

4 Conclusion

The goal of this lab exercise was to build two different current sources, a simple current source and a modified Wilsons current source and measure their operation. The circuits were first simulated in PSPICE to verify the proper circuit operation, then the circuts were built in-lab and measured using differen load resistors. This allowed the output resistance of both current sources to be measured.

All values found during the in-lab portion made sense and were within margin of error. Any differences in the experimentally found values and the values that were calculated can be attributed to the fact that the reference resistors used were not the exact calculated values.