MOSFET Cascode and BJT Widlar Current Sources

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Objective

Design and test a 30 μA BJT Widlar current source and a 300 μA MOSFET Cascode current source. For both designs, the dynamic output resistance and the voltage compliances were determined through simulations and experimental data.

Project Overview

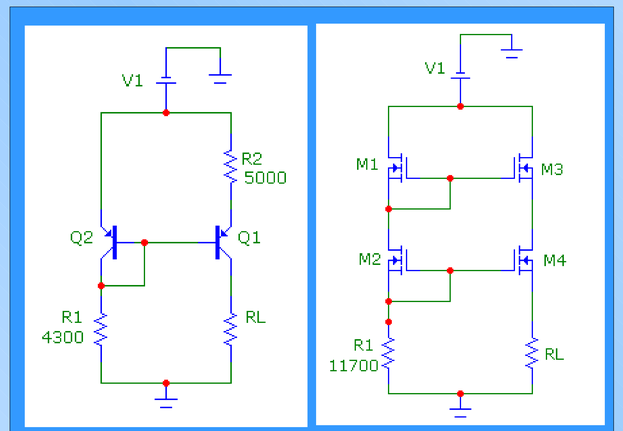
In designing the current sources, two models were used. A constant DC current, called the reference current, was generated at one location. This current was then replicated at the output node of the circuit, which was then passed to a load resistor. For the BJT Widlar current source, a reference current of 30 μA was needed. For the MOSFET Cascode current source, a reference current of 300 μA was needed.

The BJT Widlar current source operates by connecting two BJTs by their bases: this forces the reference current and the output current to be the same. An emitter degeneration resistor is attached to Q1 in order to increase the source's output resistance.

The MOSFET Cascode current source operates by using four MOSFETS. As shown in the circuit diagram, the transistors on the left-hand side of the circuit are used to set the gate voltages of the right-hand transistors, which then generate the output current.

Design and Simulation

To achieve the reference currents required for each model, theoretical and simulated analysis was performed. It was determined from examining the basic Widlar model that PNP BJTs were needed to source a current to an unknown load (R_L). Simulations using 2N3906 transistors, an input voltage of +10 volts and an arbitrary resistor of 4300 Ω (R1) showed that a 5 kΩ resistor (R2) was needed to set up the reference current that would be mirrored to the load.



(Above, left) BJT Wildar current source circuit schematic
(Above, right) MOSFET Cascode current source circuit schematic.

Examination of the basic Cascode model that P-channel MOSFETS were needed to source a current to an unknown load (R_L). Using BS250P transistors, and an input voltage of +10 volts, it was found that a 11.7kΩ resistor (R1) was needed to set up the reference current that would be mirrored to the load.

Simulations were then conducted to confirm the calculations for both circuits; both operated properly in MicroCap. Graphs of the current to the load (I_L) vs. the output voltage to the load (V_o) were made to determine the dynamic output resistance and voltage compliance.

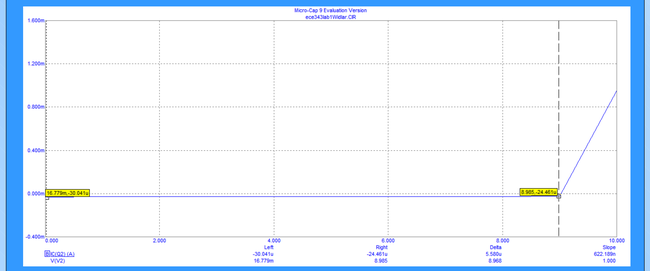
From the simulations, the MOSFET source had a compliance from 0 V to 8.971 V. The source exhibits a "knee" at 6.476 V: this is when only one of the MOSFETs has broken down. Before the "knee", the source has an output impedance of 11.322 MΩ. After the knee, the current decreases much more rapidly with an increasing output voltage. The output impedance decreases to 351.4 kΩ after this point.

The Widlar source has a voltage 0 to 8.985 V, and an output impedance of 1.607 MΩ.

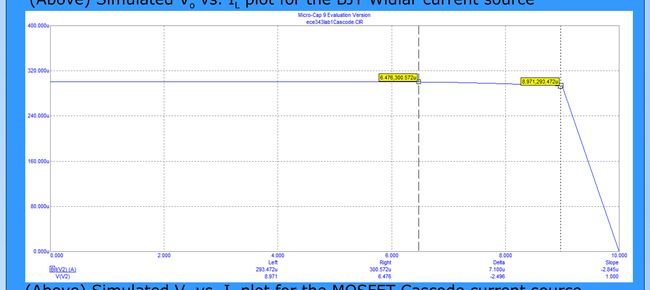
Implementation and Results

Experimental tests utilized an Agilent E3630A DC Power Supply, a Keithley 175 Auto-ranging Multimeter, a Tenma 72-1024 LCR Meter and a solderless breadboard.

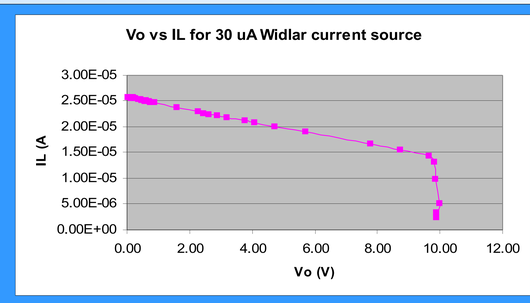
To measure the dynamic output resistance and the voltage compliance, the resistive load (R_L) was incrementally changed from 1000 Ω to 3 MΩ. The voltage drop across the resistor was then measured with the multimeter, and the current through the load calculated using Ohm's Law. A graph of the data points taken to verify the dynamic output resistance and voltage compliance. The dynamic output resistance can be found by taking the inverse of the slope of the graph's straight-line portion, and the voltage compliance is the range of voltages at which the circuit still produces a constant current.



(Above) Simulated V_o vs. I_L plot for the BJT Widlar current source

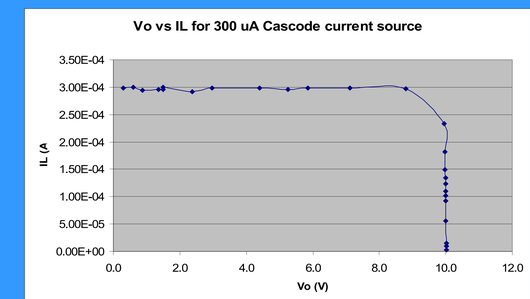


(Above) Simulated V_o vs. I_L plot for the MOSFET Cascode current source



(Above) Current to the Load (IL) vs. the Output Voltage at the Load (Vo) for the Widlar current source

(Below) Current to the Load (IL) vs. the Output Voltage at the Load (Vo) for the Cascode current source



Conclusion

The BJT Widlar current source produced an experimental dynamic output resistance of 861 kΩ and a voltage compliance of 0V to 9.639V. The MOSFET Cascode current source produced an experimental dynamic output resistance of 6.506 MΩ and a voltage compliance of 0V to 8.801V.

The MOSFET Cascode current source produced a more consistent output current than the Widlar source, and has a much larger output resistance; however, it can only support a load resistance of less than 30 kΩ before the source stops producing the expected current. The Widlar source can operate with a load resistance of up to 669 kΩ. The MOSFET current source would be suited for most purposes. However, the Widlar source would be appropriate for use with high-impedance loads.