

The circuit shown below is the MOS version of a Wilson current mirror. Assume all transistors are exactly matched and biased in the saturation region. This results in a very good current matching. In other words $I_{OUT} = I_{IN}$, to a very high degree of accuracy.

$I_{IN} = I_{OUT} = 50\mu A$. The over-voltage (v_{ov} , or $v_{gs} - V_t$) is 100mV and the threshold voltage V_t is 300mV for all devices. The Early voltage V_A is 10V.
Useful small signal parameters are: $g_m = 2I_D/v_{ov}$, and $r_o = V_A/I_D$.

- 1) What is the minimum voltage V_{OUT} that can be tolerated to ensure operation as a current source? (1 point)
- 2) What is the output resistance of this current source? Develop both an expression and determine a numerical value for the resistance. (3 points)

A useful approximation, which greatly simplifies the analysis of question 2, is to ignore the output resistance of the two diode-connected transistors (M_4 and M_1). Other than that this is best solved by the usual method of applying a test source to the output.

