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Lecture 14
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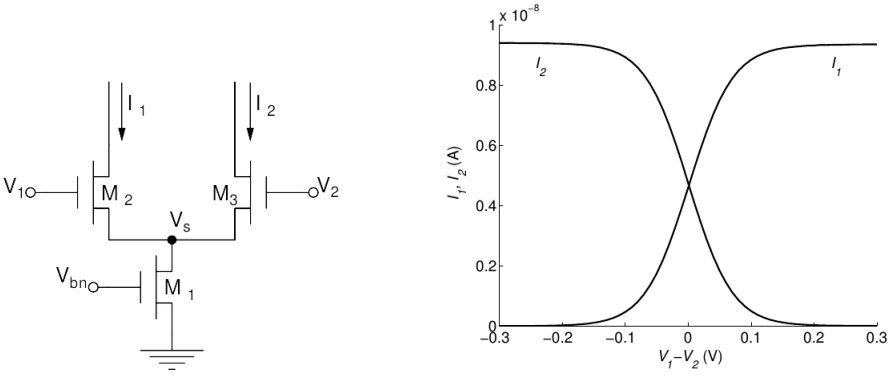
Exercise 10.1: The Differential Pair



(a) Circuit Diagram (b) Current vs Voltage Difference

Figure 1: The Differential Pair

1. The circuit in fig. 1 is called a *differential pair*. The current I_1 (and I_2) flowing through transistor M_2 (and M_3) as a function of the voltage difference $V_1 - V_2$ looks as drawn in the given plot.

   This circuit is used ubiquitously in analogue circuit design and specifically also in neuromorphic engineering. Due to which properties might it be so popular? *Hint:* Think about the first part of the name of this circuit and about its asymptotic behavior.

2. Find out which function is plotted in fig. 1.(b). *I.e.* calculate the currents I_1 and I_2 as a function of the voltages V_1 and V_2 for the differential pair. By assuming that all transistors are in subthreshold domain in saturation regime, you can approximate the current I flowing through a transistor by:

$$I = I_0 \exp\left(\frac{\kappa V_g - V_s}{U_T}\right).$$

   Here I_0, κ and U_T are parameters. V_g is called the '*gate voltage*', and V_s the '*source voltage*'; see fig. 2. Then rearrange your terms to express the currents as a function of the voltage difference $V_1 - V_2$.

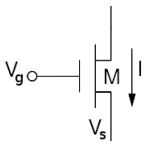


Figure 2: Voltages and current in a simple transistor.