A Simple Variable-Width CMOS Bump Circuit

Bradley A. Minch

Mixed Analog-Digital VLSI Circuits & Systems Lab
Franklin W. Olin College of Engineering
Needham, MA 02492

bradley.minch@olin.edu

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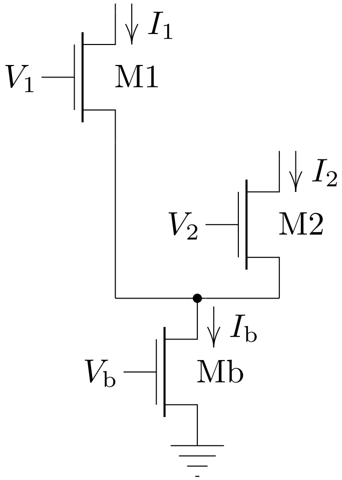
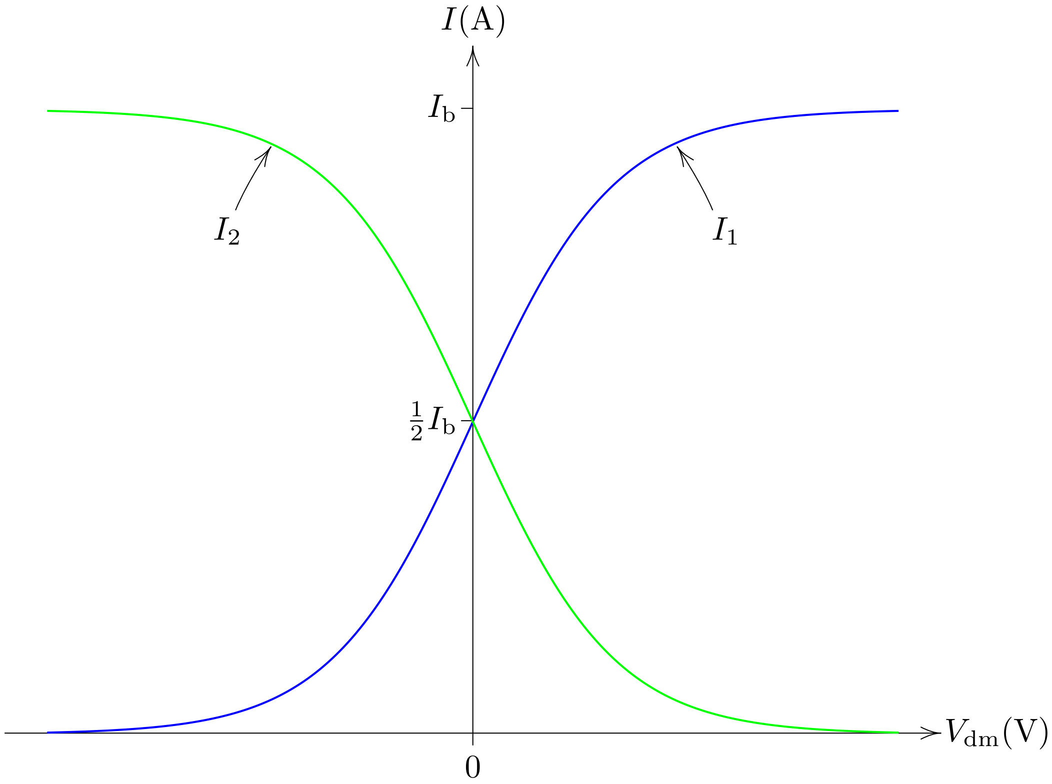
Delbrück's Original Bump Circuit



$$I_{1,2} = \frac{I_b}{1 + e^{\mp \kappa V_{dm}/U_T}}$$

$$V_{dm} = V_1 - V_2$$



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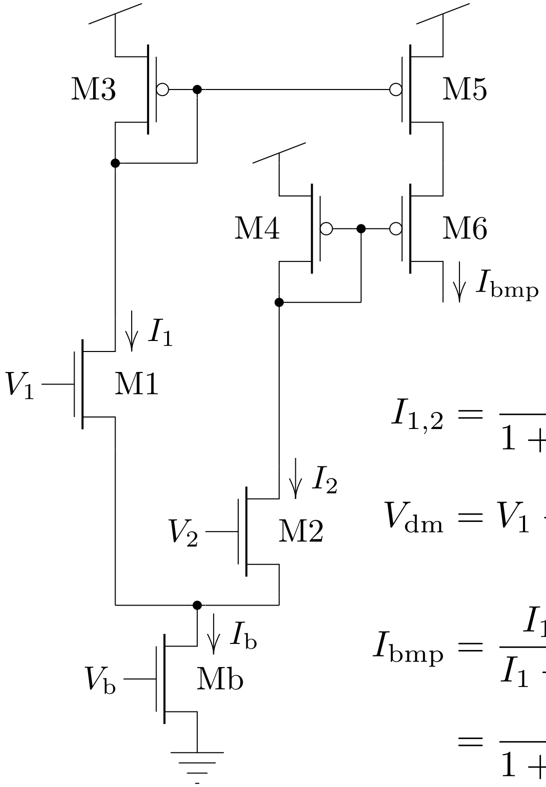
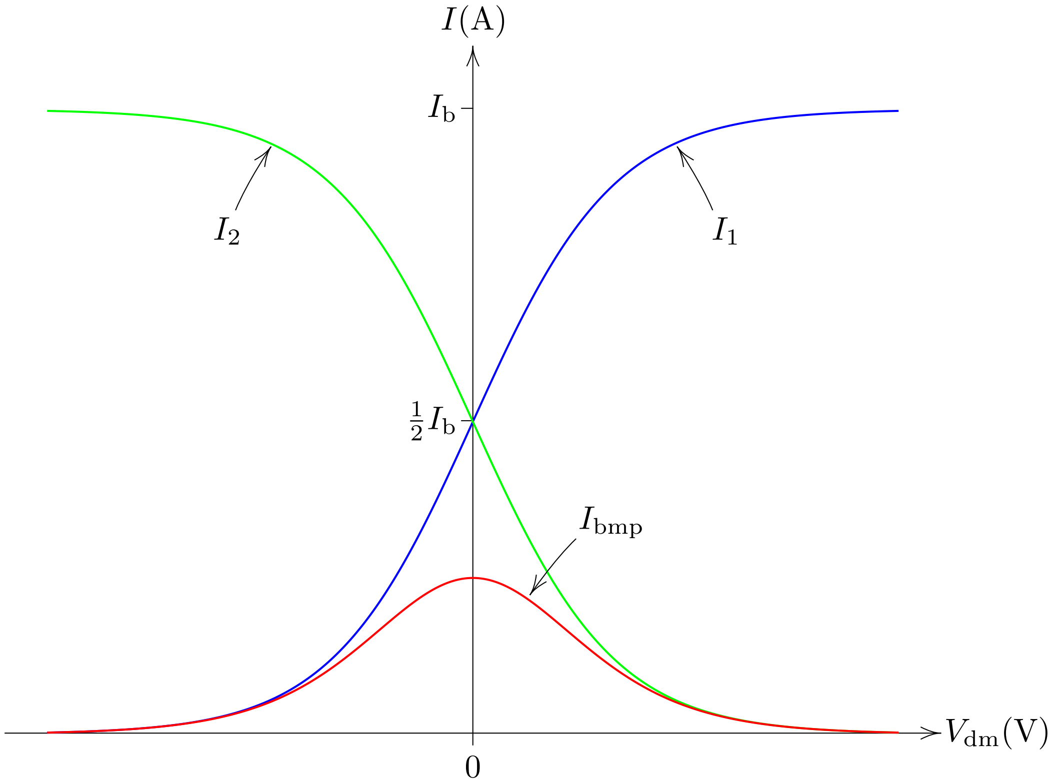
Delbrück's Original Bump Circuit



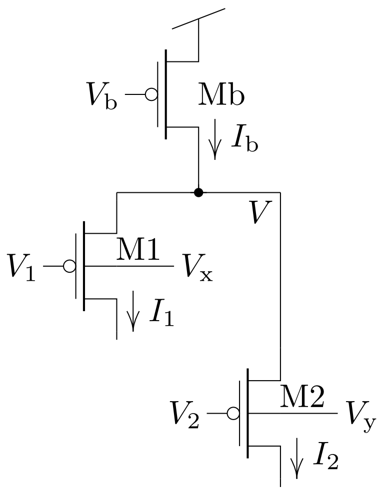
$$I_{1,2} = \frac{I_{\mathrm{b}}}{1 + e^{\mp\kappa V_{\mathrm{dm}}/U_{\mathrm{T}}}}$$

$$V_{\mathrm{dm}} = V_1 - V_2$$

$$I_{\mathrm{bmp}} = \frac{I_1 I_2}{I_1 + I_2} = \frac{I_{\mathrm{b}}/2}{1 + \cosh\left(\kappa V_{\mathrm{dm}}/U_{\mathrm{T}}\right)}$$



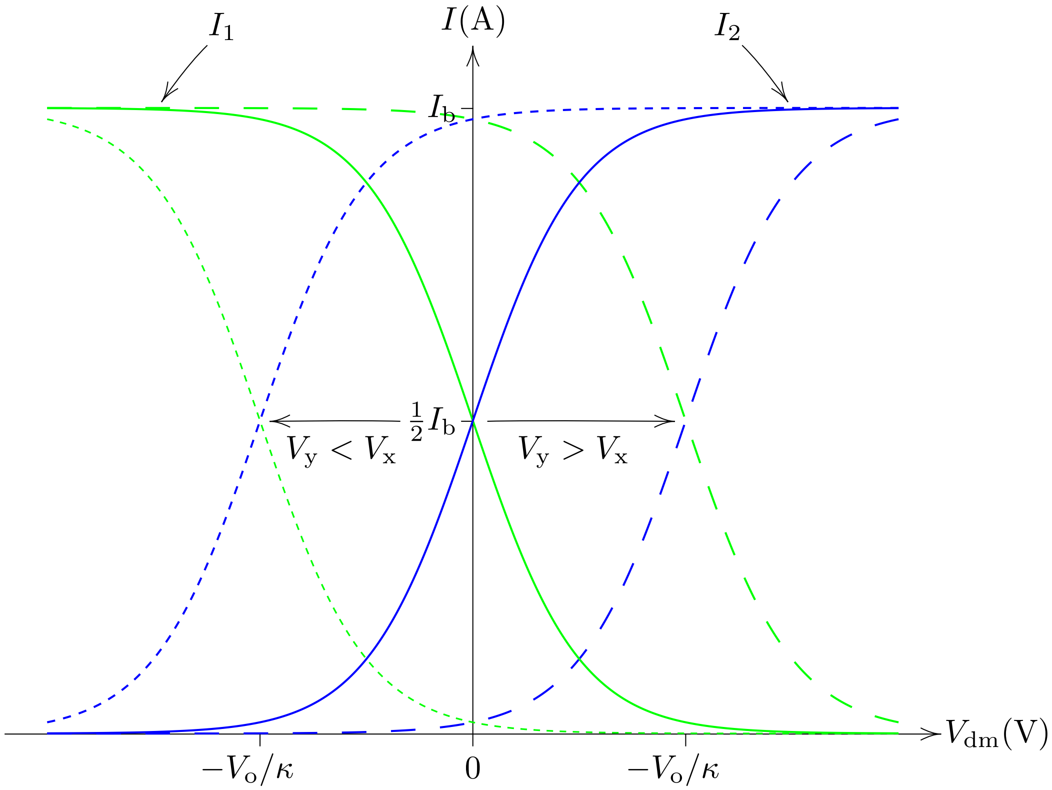
Asymmetric Differential Pair



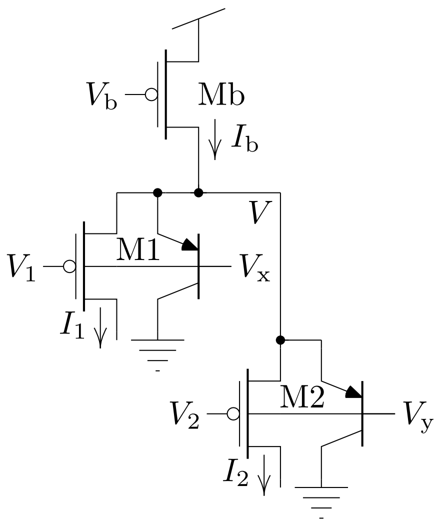
$$I_{1,2} = \frac{I_b}{1 + e^{\pm V_o/U_T} e^{\pm \kappa V_{dm}/U_T}}$$

$$V_{dm} = V_1 - V_2, \quad V_o = (1-\kappa)(V_x - V_y)$$

$$V \le \min\left(\kappa V_1 + (1-\kappa) V_x,\ \kappa V_2 + (1-\kappa) V_y\right) + \kappa (V_{dd} - V_b)$$



Asymmetric Differential Pair

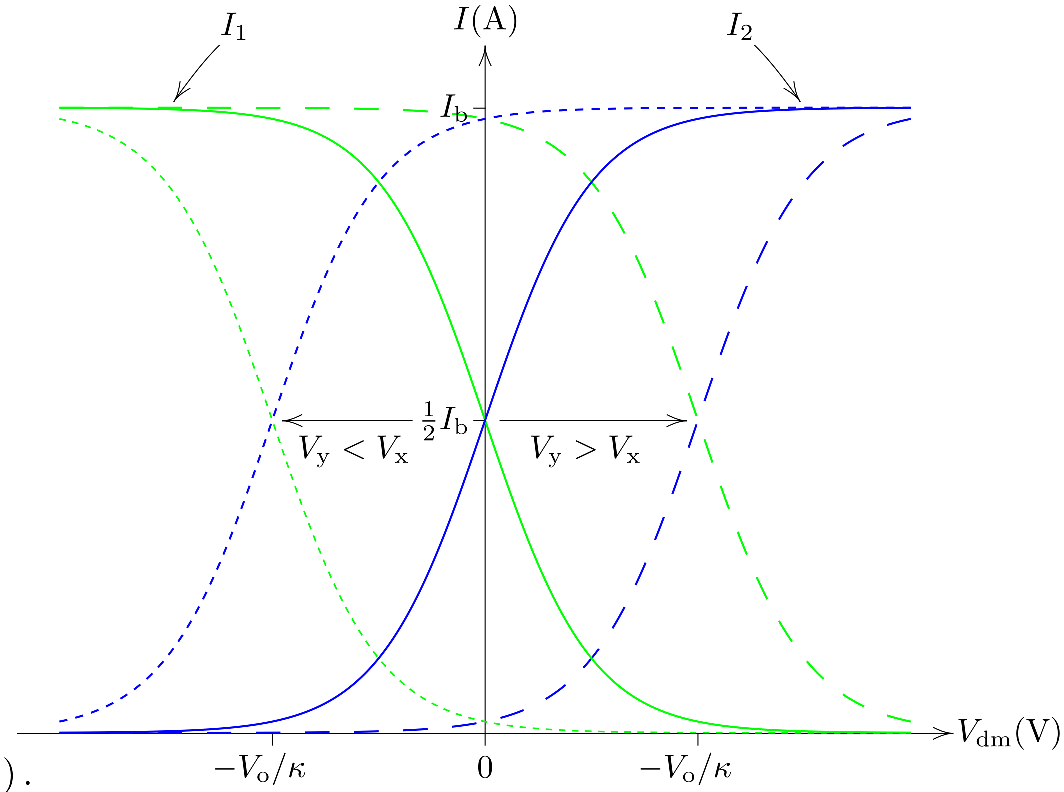


To ensure proper operation, we should have

$$V < \min\left(V_x,\, V_y\right),$$

which we can guarantee if we require

$$\min\left(\kappa V_1 + (1-\kappa)V_x,\, \kappa V_2 + (1-\kappa)V_y\right) + \kappa\left(V_{dd} - V_b\right) < \min\left(V_x,\, V_y\right).$$



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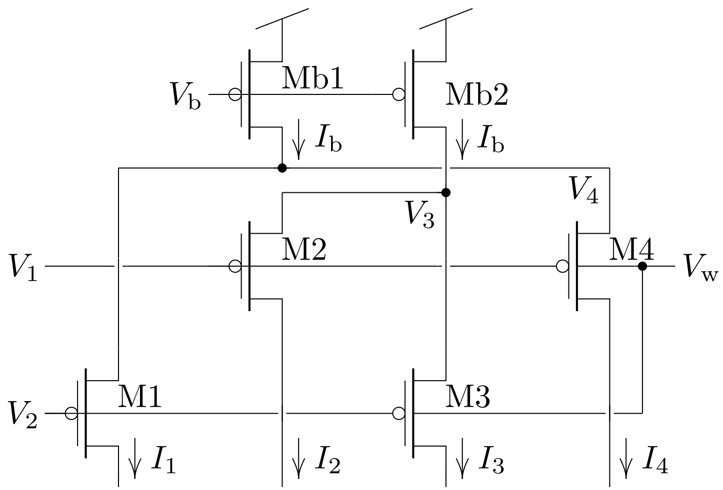
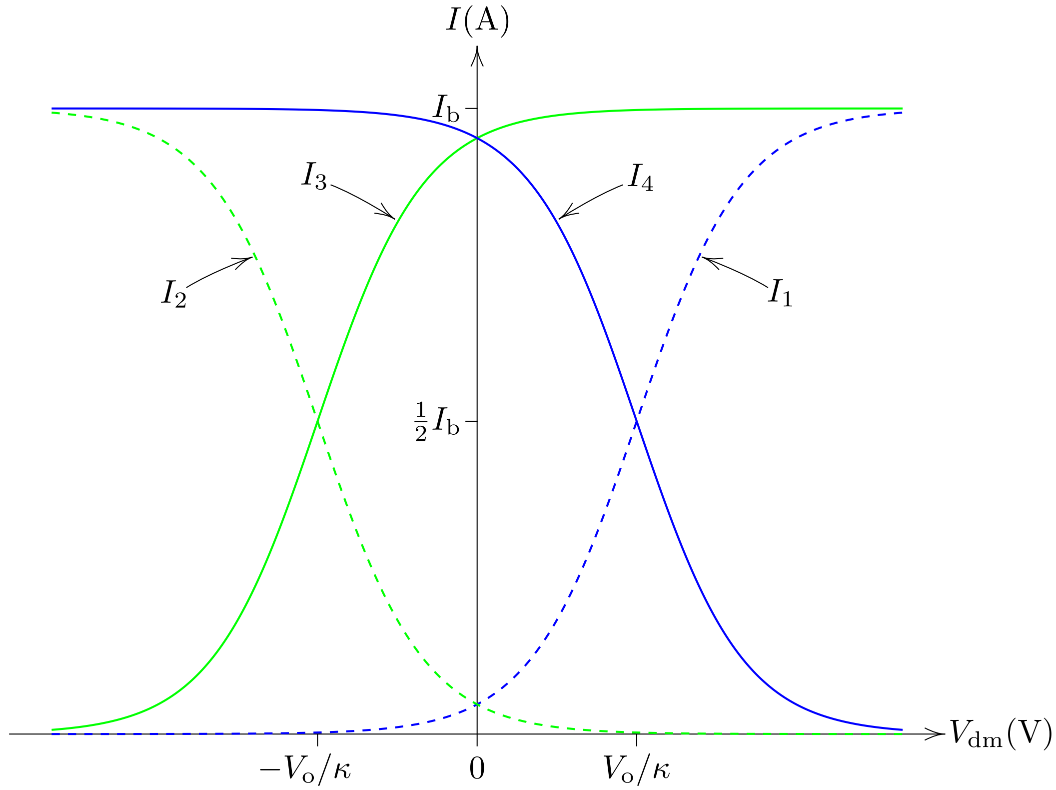
Principle of Circuit Operation



$$I_{1,2} = \frac{I_b}{1 + e^{+V_o/U_T} e^{\mp \kappa V_{dm}/U_T}}$$

$$I_{3,4} = \frac{I_b}{1 + e^{-V_o/U_T} e^{\mp \kappa V_{dm}/U_T}}$$

$$V_{dm} = V_1 - V_2, \quad V_o = (1-\kappa)(V_{dd} - V_w)$$



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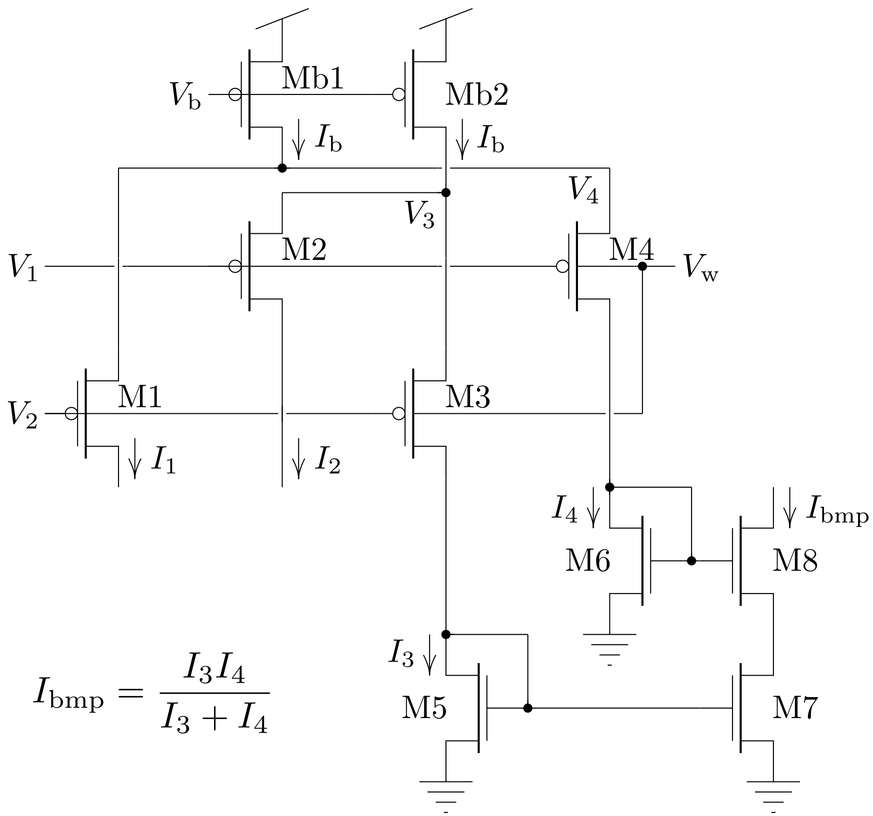
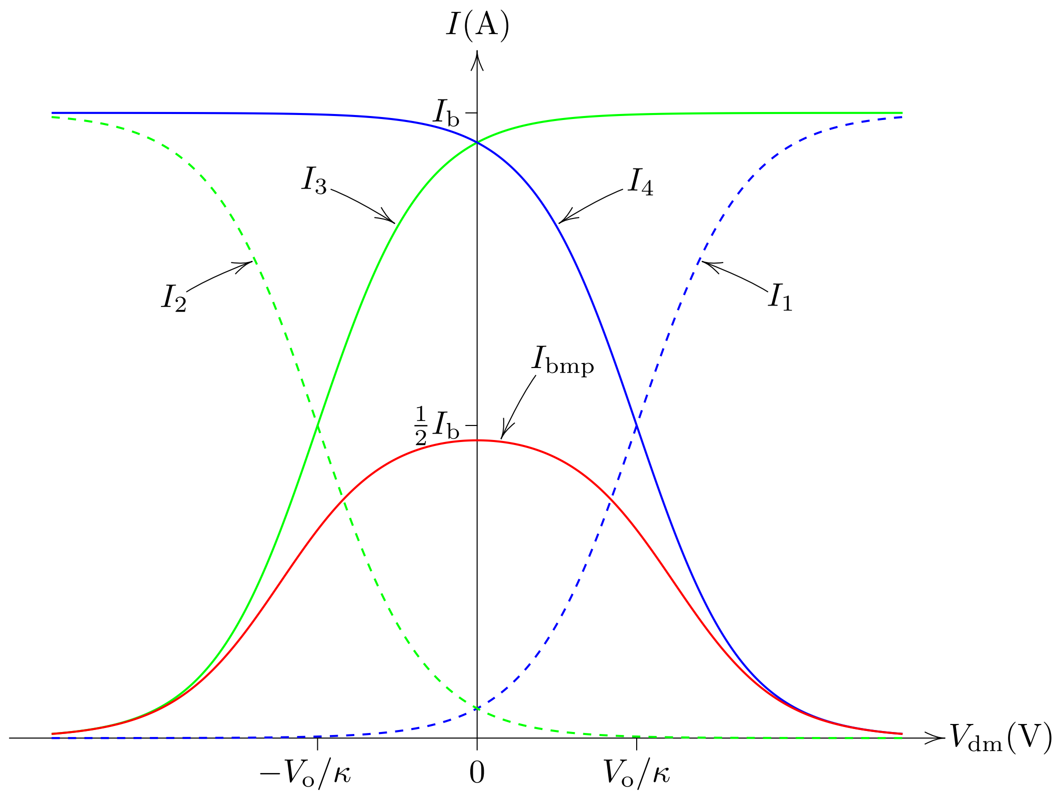
Principle of Circuit Operation



$$I_{bmp} = \frac{I_3 I_4}{I_3 + I_4}$$



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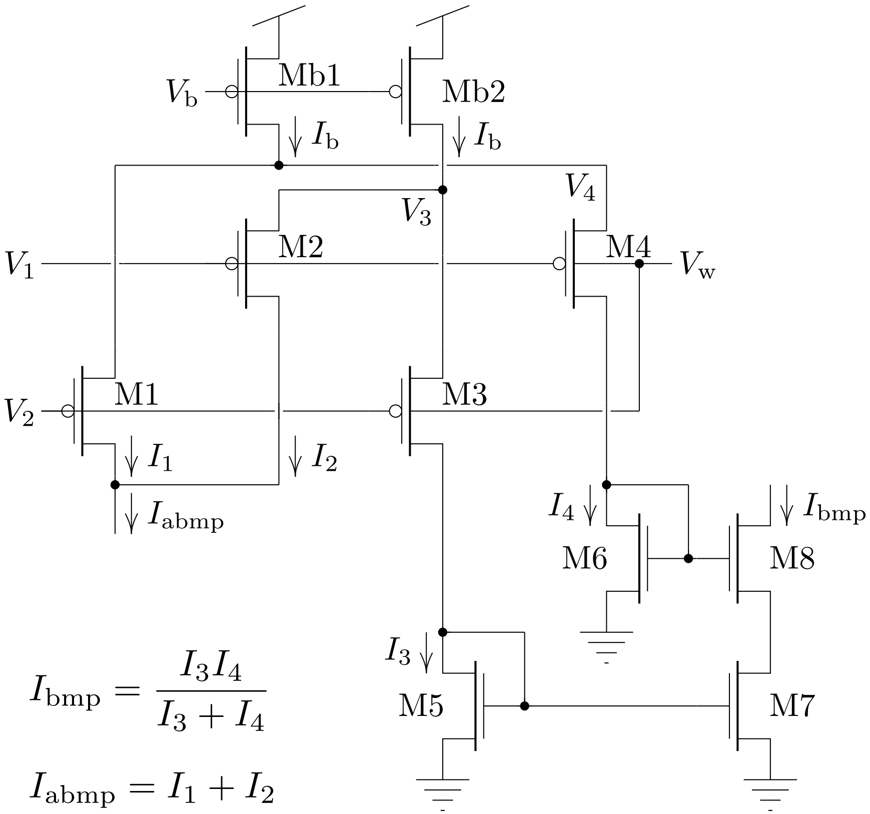
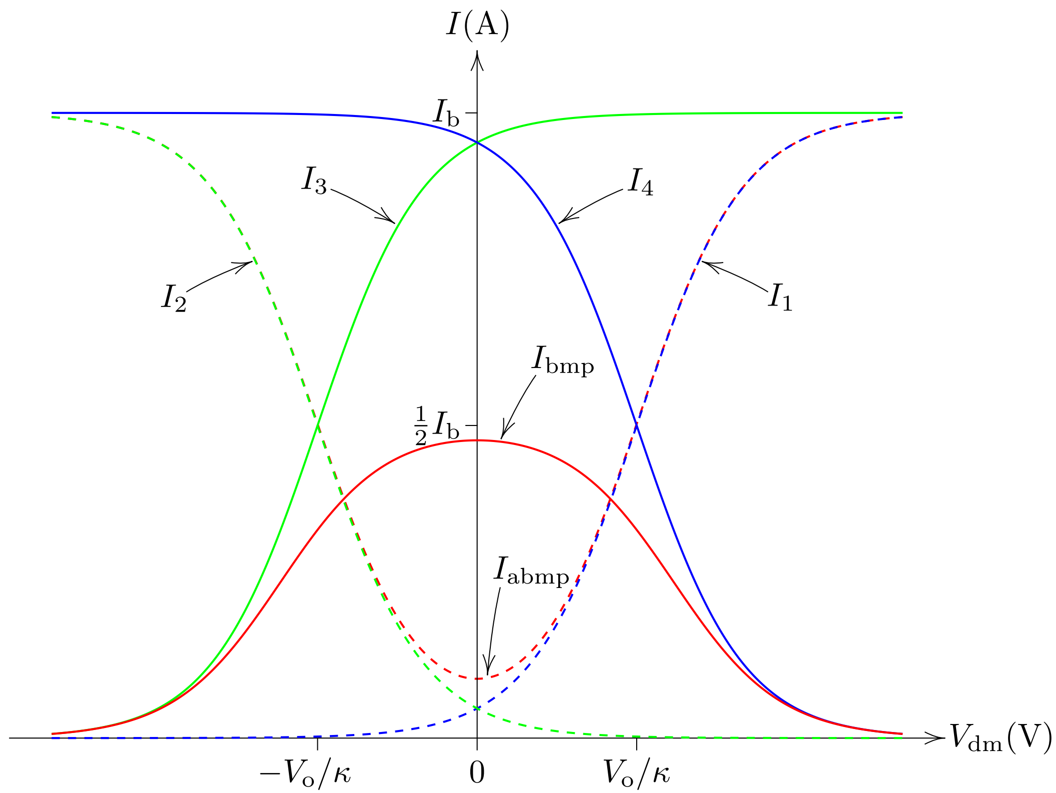


$$I_{bmp} = \frac{I_3 I_4}{I_3 + I_4}$$

$$I_{abmp} = I_1 + I_2$$



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Principle of Circuit Operation

Given that

$$I_{1,2} = \frac{I_\mathrm{b}}{1 + e^{+V_\mathrm{o}/U_\mathrm{T}} e^{\mp \kappa V_\mathrm{dm}/U_\mathrm{T}}} \quad \text{and}$$

$$I_{3,4} = \frac{I_\mathrm{b}}{1 + e^{-V_\mathrm{o}/U_\mathrm{T}} e^{\mp \kappa V_\mathrm{dm}/U_\mathrm{T}}},$$

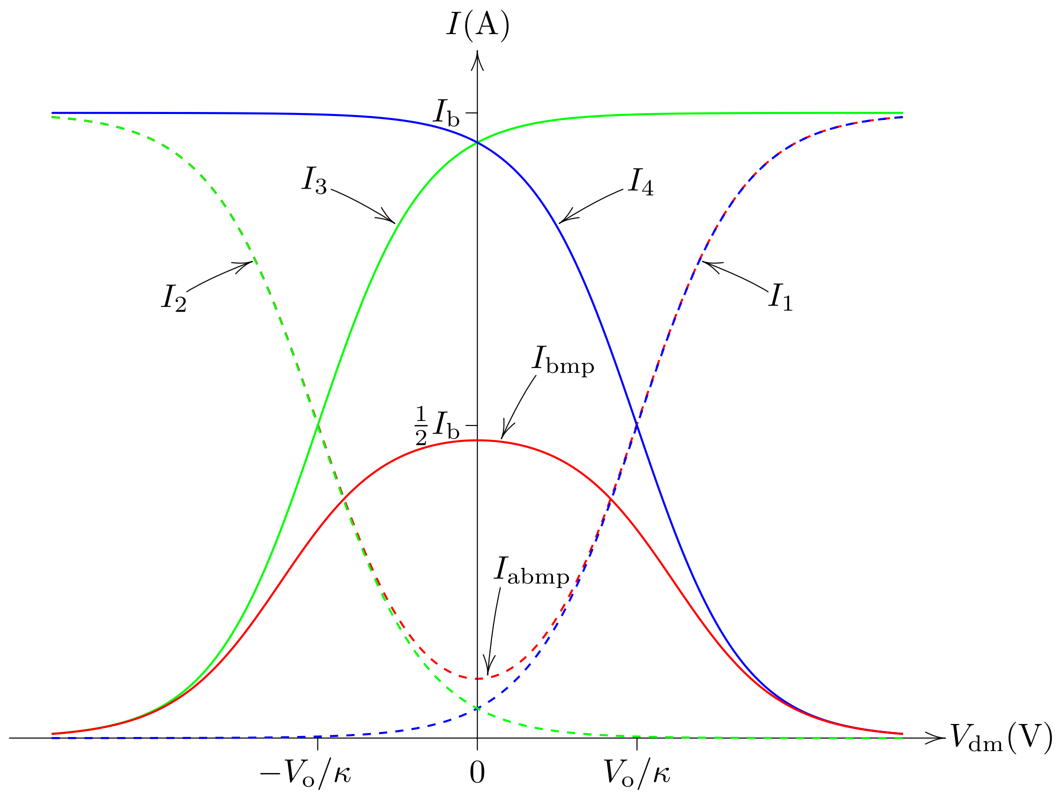
where

$$V_\mathrm{dm} = V_1 - V_2 \quad \text{and} \quad V_\mathrm{o} = (1-\kappa)\,(V_\mathrm{dd} - V_\mathrm{w})\,,$$

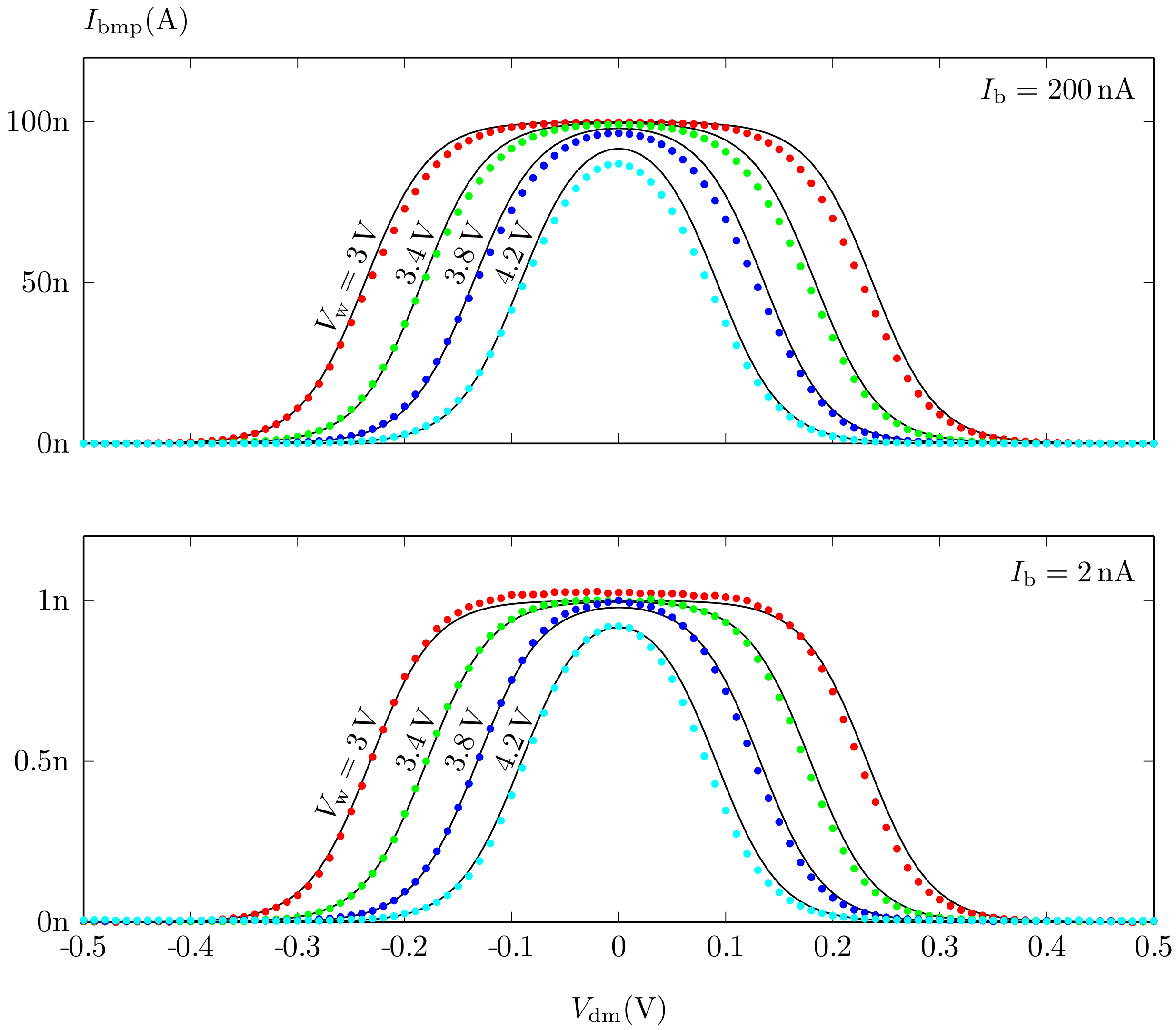
we can show that

$$I_\mathrm{bmp} = \frac{I_3 I_4}{I_3 + I_4} = \frac{I_\mathrm{b}/2}{1 + e^{-V_\mathrm{o}/U_\mathrm{T}} \cosh\left(\kappa V_\mathrm{dm}/U_\mathrm{T}\right)} \quad \text{and}$$

$$I_\mathrm{abmp} = I_1 + I_2 = I_\mathrm{b} \cdot \frac{e^{-V_\mathrm{o}/U_\mathrm{T}} \cosh\left(\kappa V_\mathrm{dm}/U_\mathrm{T}\right)}{1 + e^{-V_\mathrm{o}/U_\mathrm{T}} \cosh\left(\kappa V_\mathrm{dm}/U_\mathrm{T}\right)}.$$



Bump Circuit Transfer Characteristics



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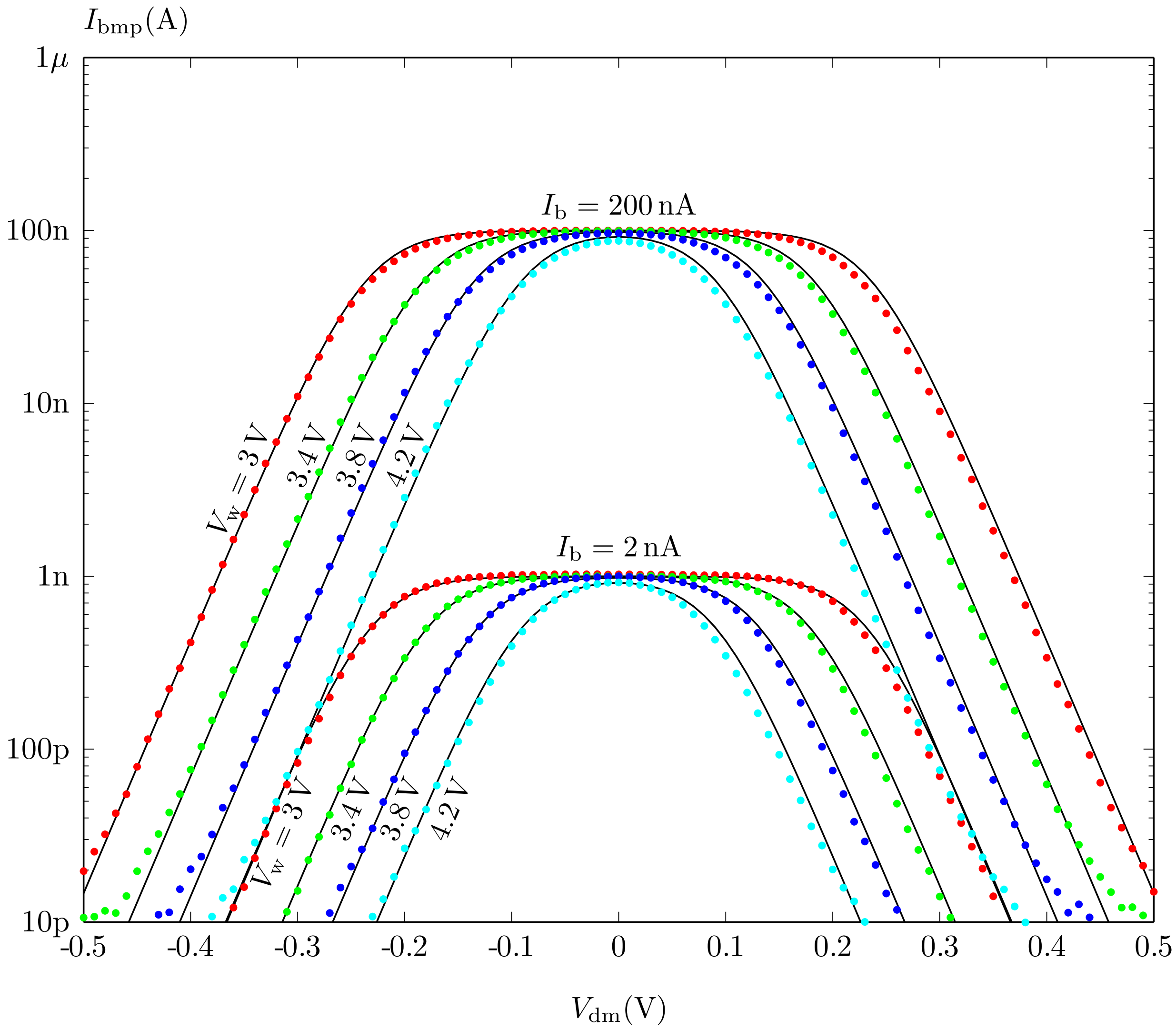
Bump Circuit Transfer Characteristics



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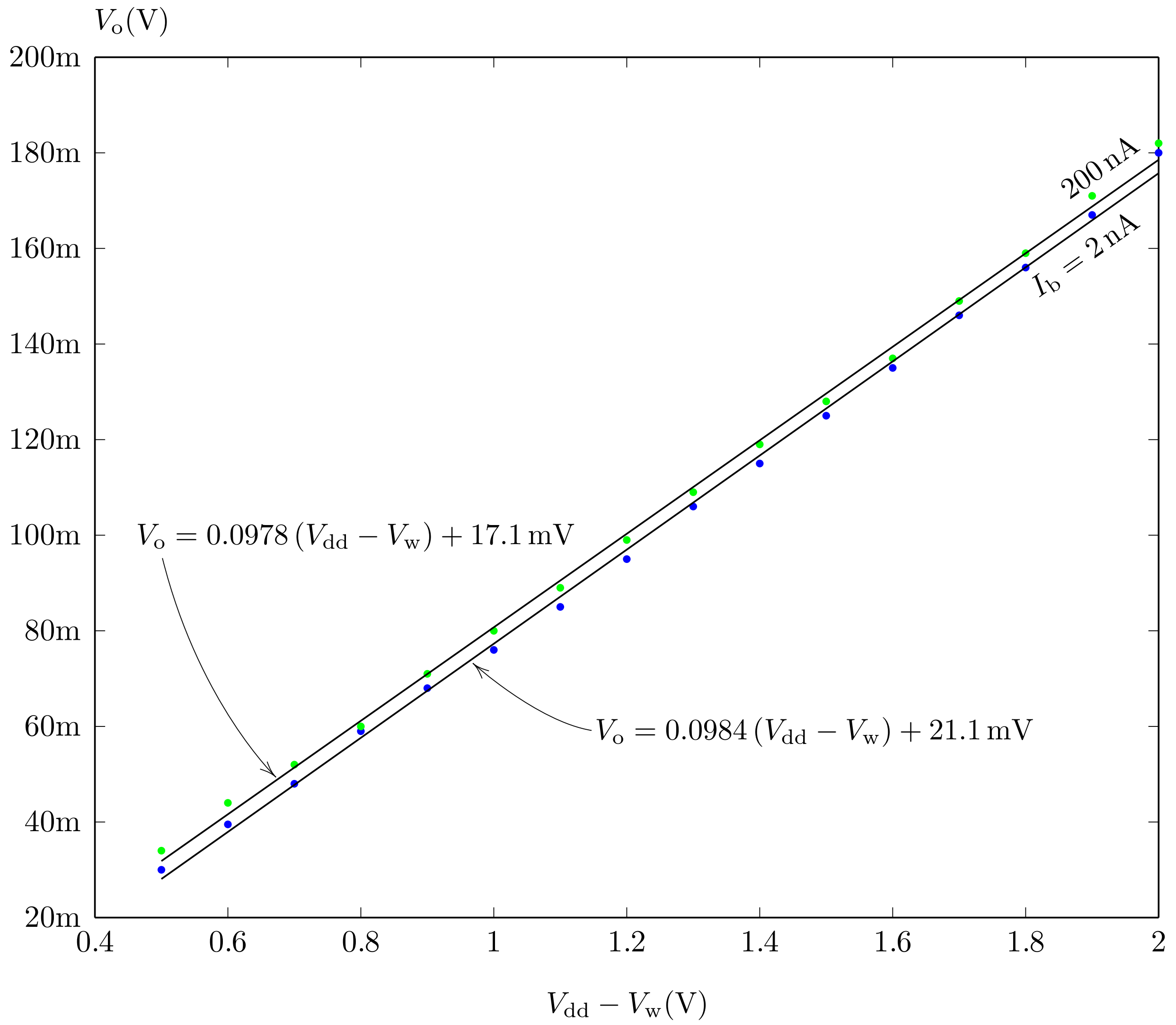
Bump Circuit Transfer Characteristics



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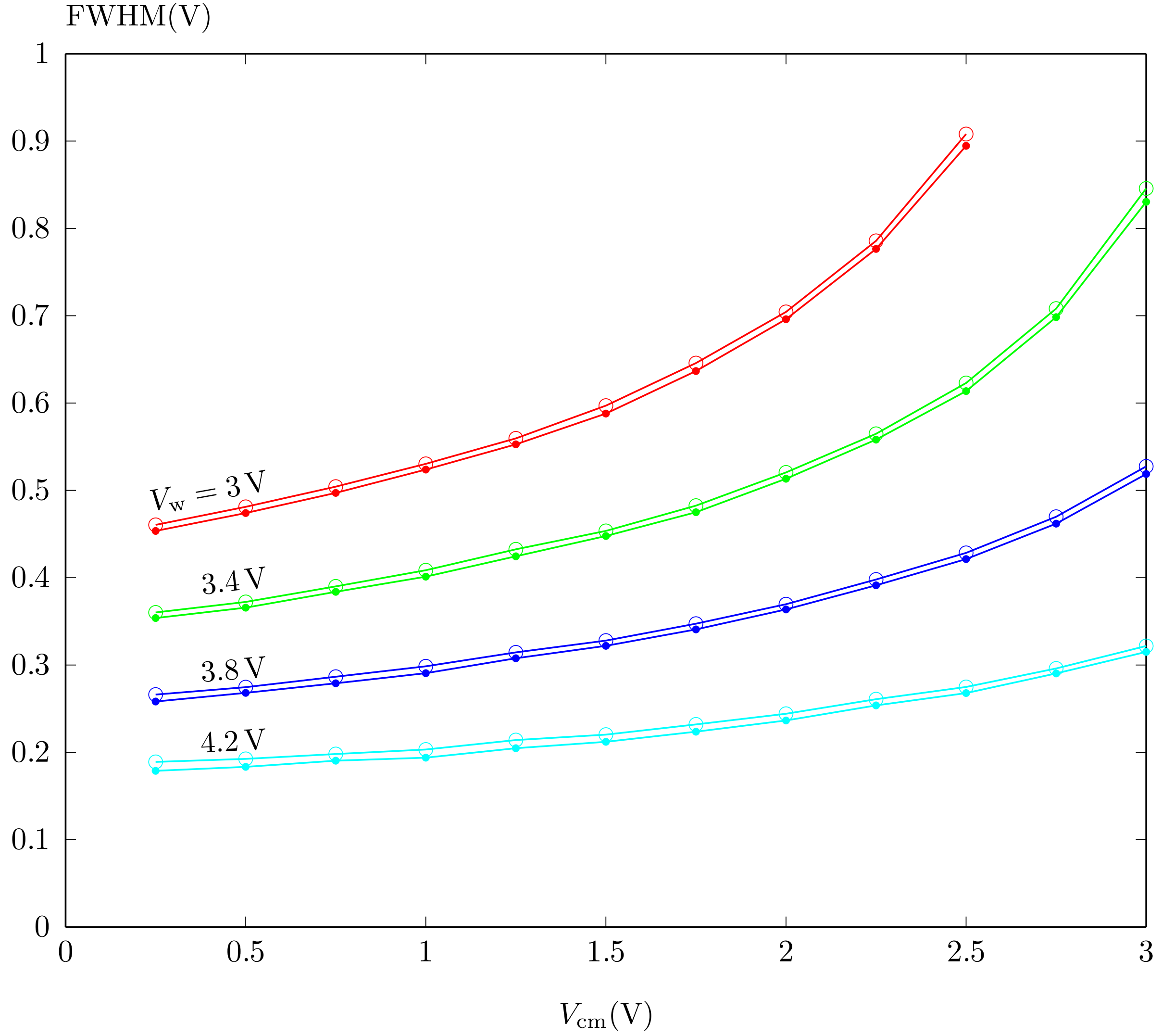
Effect of Common-Mode Input Voltage



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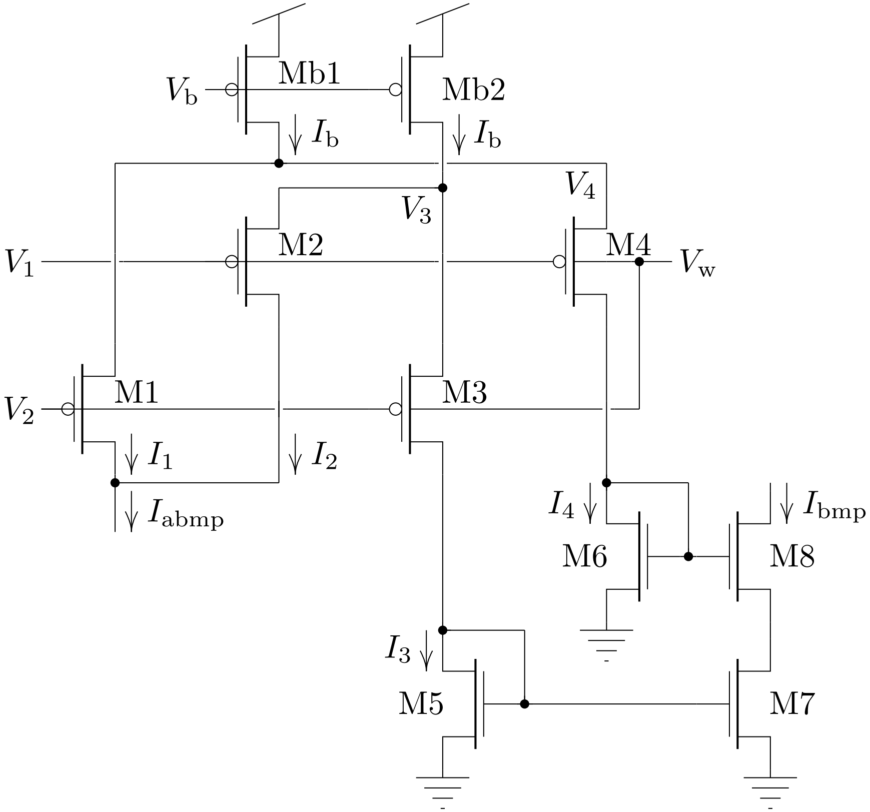
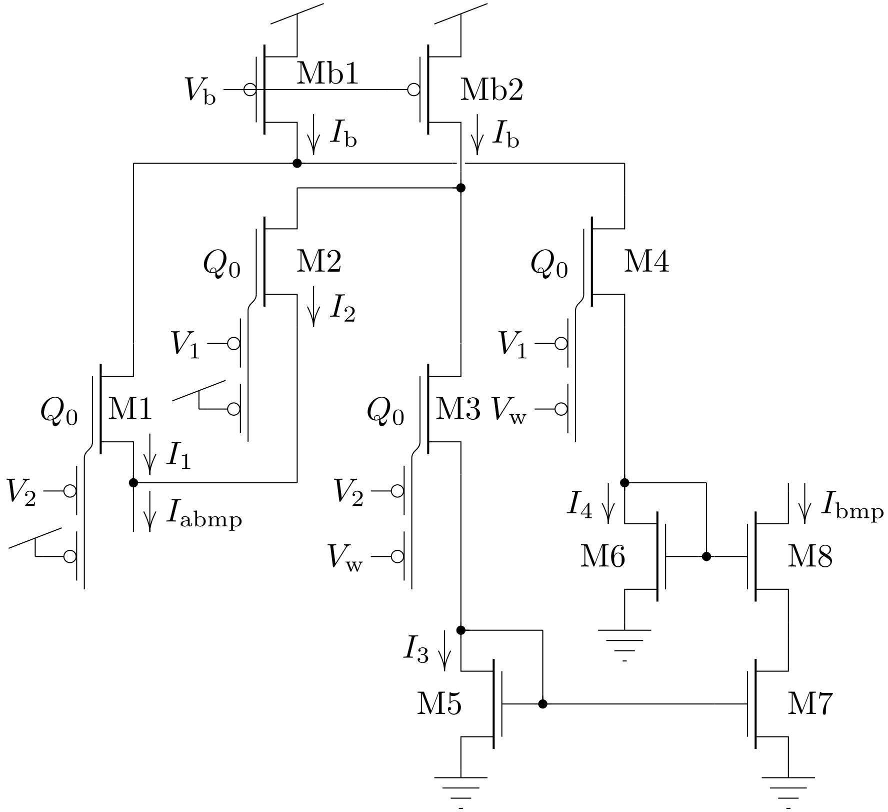
Floating-Gate Variations on a Theme





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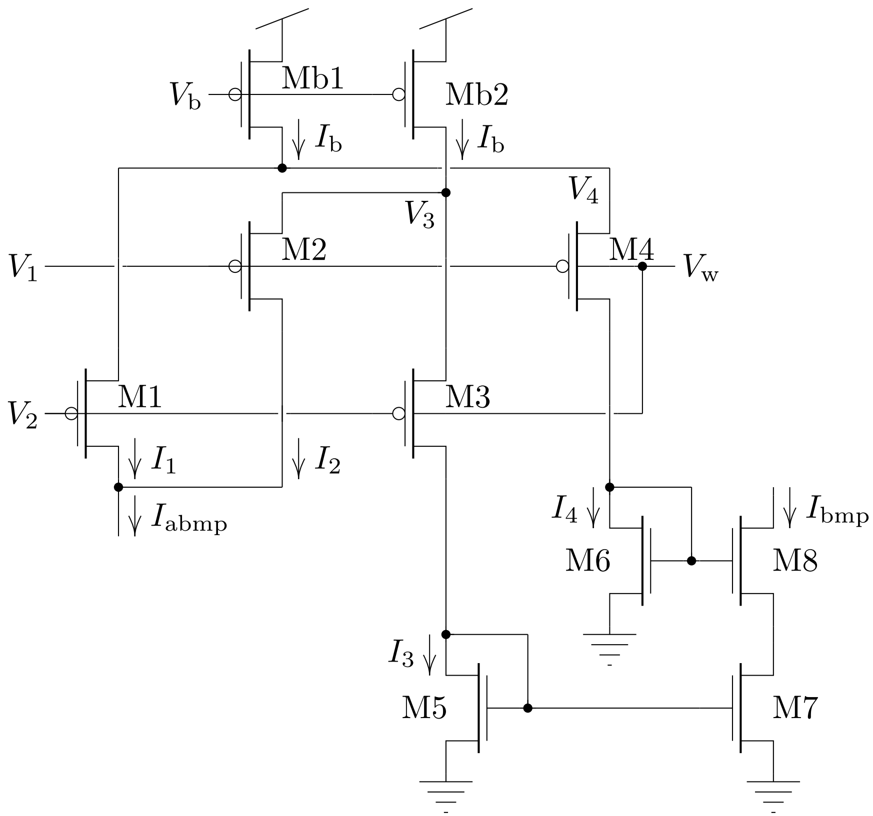

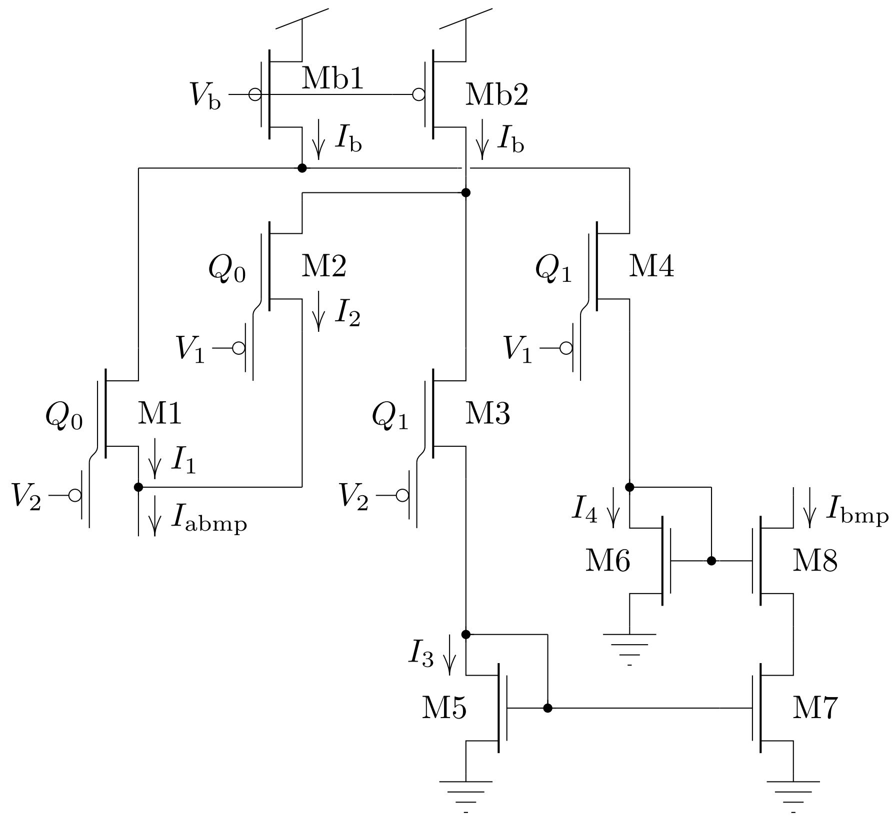

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Floating-Gate Variations on a Theme