Design Illustration of a Symmetric OTA using Multiobjective Genetic Algorithms

OUTLINE

- Motivation and related work
- Symmetric OTA
- Multiobjective optimization using genetic algorithms
- Design optimization method
- Simulations and results
- Conclusions and future development

MOTIVATION AND RELATED WORK

- **Manual analog circuit design:**
  - very difficult and complex task
  - large number of conflicting requirements

- **Automatic circuit design:**
  - great development over the past decade
  - includes GAs in the design process
  - industrial simulator to close the loop
  - multiobjective optimization

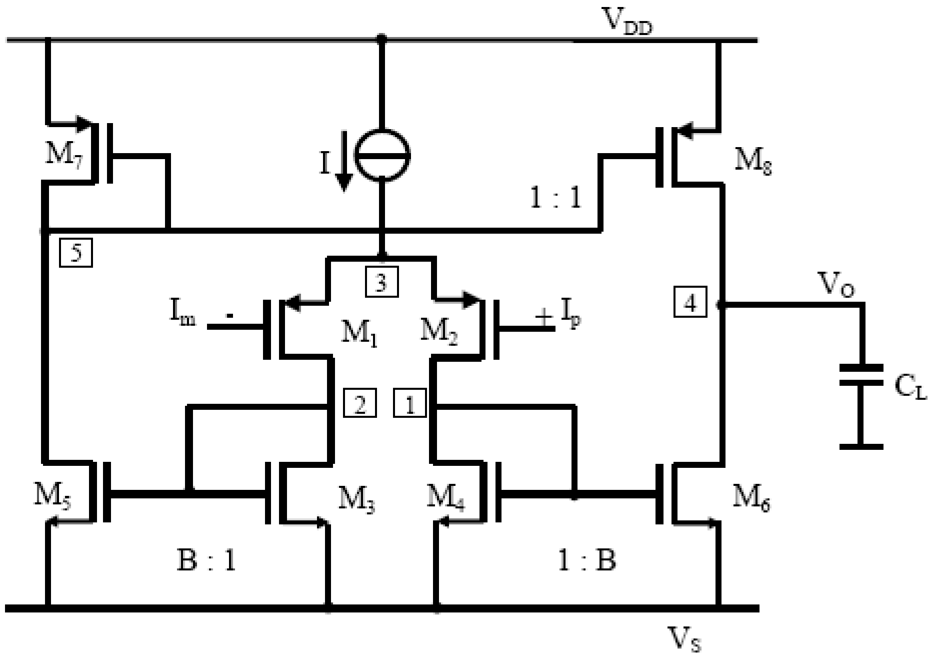
Symmetric OTA
Circuit description

- a differential pair
  M_1, M_2

- three current mirrors
  M_7-M_8, M_3-M_5 , M_4-M_6

- two identical current mirrors
  to load the input differential pair

- current gain B



- **design parameters** : the channel size (*W* and *L*) of all transistors
  the biasing current *I*
  the gain of the current mirror *B*

Symmetric OTA
Operating equations

$$A_{v0} = \frac{v_o}{v_i} = \frac{i_6 R_{N4}}{v_i} = \frac{B i_2 R_{N4}}{v_i} == \frac{B g_{m1} v_i R_{N4}}{v_i} = B g_{m1} R_{N4}$$

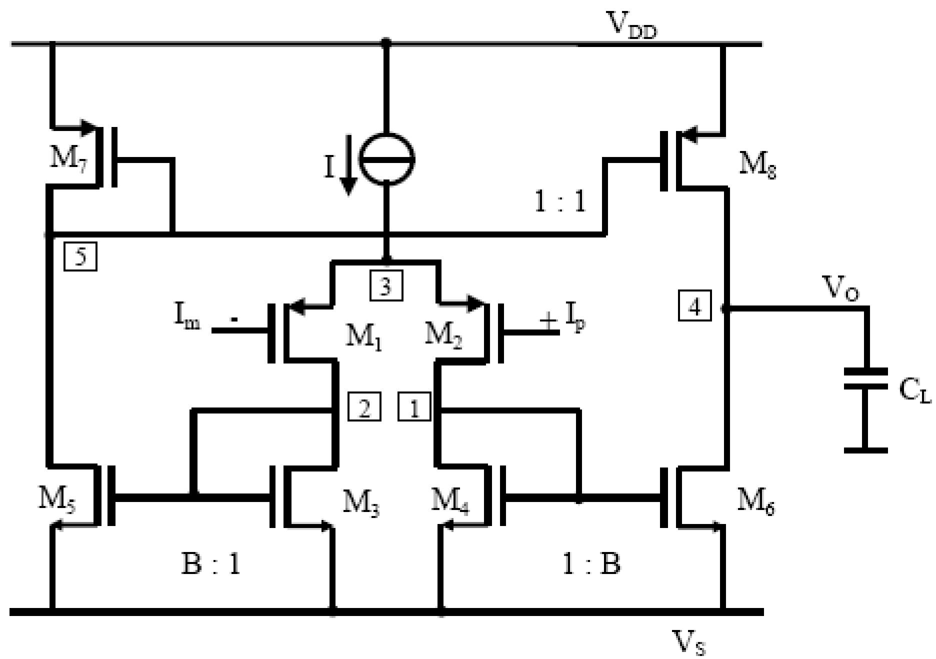
$$A_{v0} = 2\sqrt{K_p}\,\frac{V_{Ep} L_8 V_{En} L_6}{V_{Ep} L_8 + V_{En} L_6}\sqrt{\left(\frac{W}{L}\right)_1}\,\frac{1}{\sqrt{I}}$$

$$BW = \frac{1}{2\pi R_{N4} C_L}$$

$$BW = \frac{1}{4\pi C_L}\,\frac{V_{Ep} L_8 + V_{En} L_6}{V_{Ep} L_8 V_{En} L_6}\, IB$$

$$Area = \sum_{i=1}^{N} W_i L_i$$

$$P = (V_{DD} - V_{SS})(I + BI) = (V_{DD} - V_{SS})(1 + B)I$$



Simplifying assumptions: fixed Length (L) and

$$\begin{cases} (W/L)_1 = (W/L)_2 \\ (W/L)_3 = (W/L)_4 \\ (W/L)_7 = (W/L)_8 \end{cases}$$

Multiobjective Optimization Using Genetic Algorithms

- General Multiobjective Optimization Problem (MOP):

Find a vector x that optimizes

$$f(x) = (f_1(x), f_2(x), \ldots, f_N(x))^T$$

subject to the following constraints:

$$g_j(x) < 0,\ j = \overline{1,\ldots,M}$$

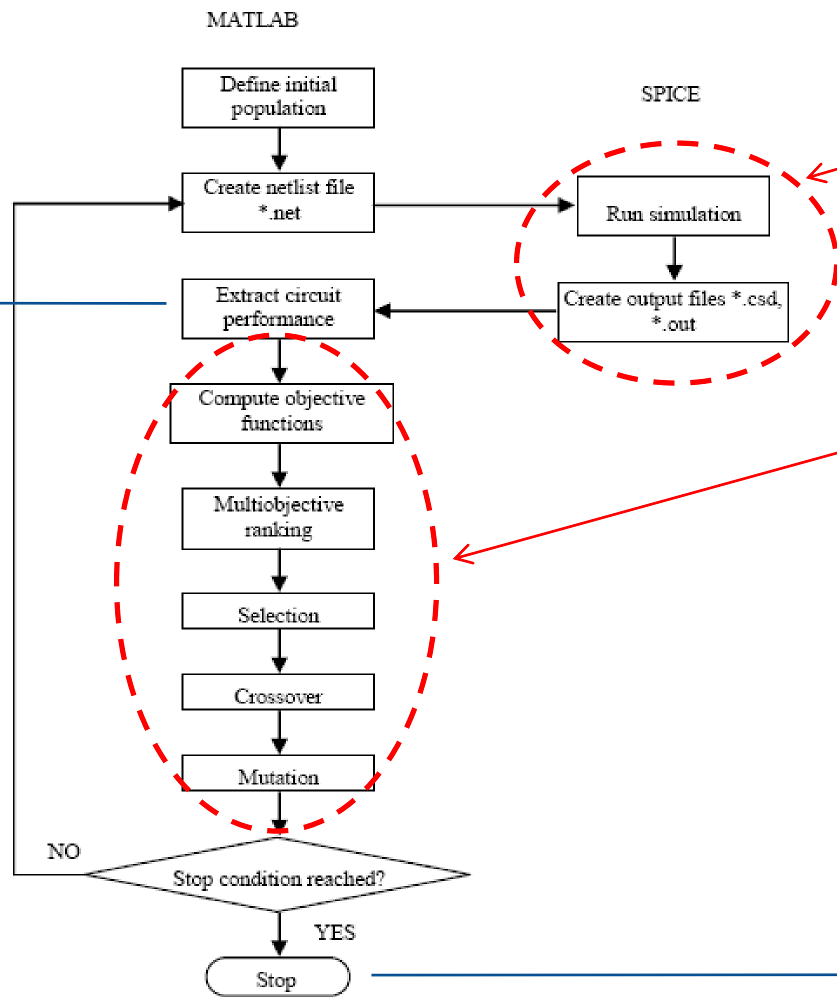
$$h_k(x) = 0, k = \overline{1,\ldots,K}$$

$$a(l) \le x(l) \le b(l), 1 \le l \le n$$

Result: several optimal objective vectors (the Pareto front)

DESIGN OPTIMIZATION METHOD

Gain
Bandwidth
Layout area
Power consumption



for each individual

multiobjective GA

multiple solutions

Simulations and results
Simulation conditions

- Chromosome: $[W_1 W_3 W_7 I]$
- Design specifications:

No.	Specification	Desired value
1	Gain	>200
2	Bandwidth	>150KHz
3	Layout area	Minimized
4	Power consumption	Minimized

- Objective functions: absolute errors, with respect to the desired values
- Settings and constraints:

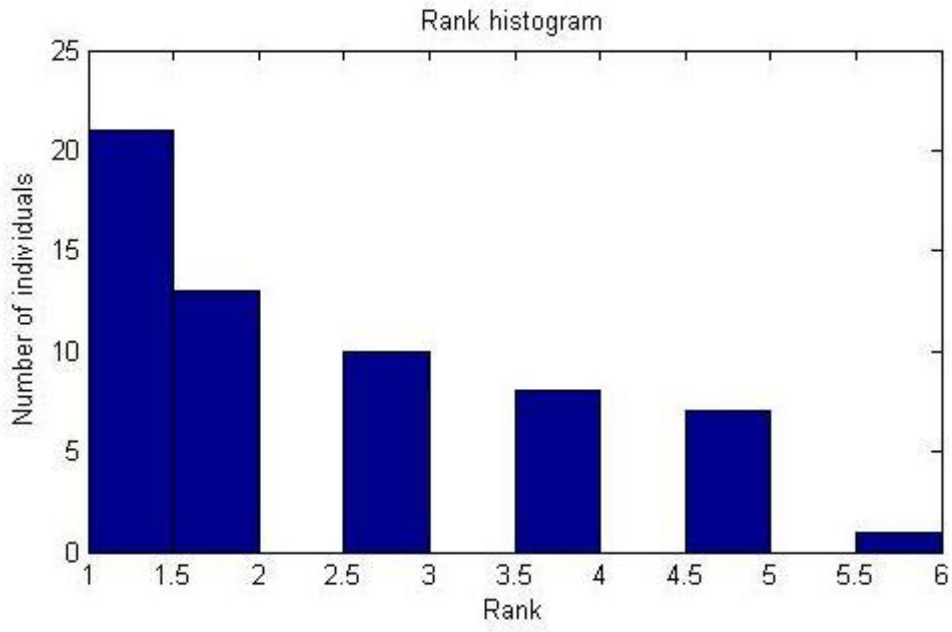
$$L_1 = L_2 = 1\mu m$$

$$L_3 = L_4 = L_5 = L_6 = 10\mu m$$

$$(W/L)_1 > 0.036I$$

Simulations and results
Results – rank histogram

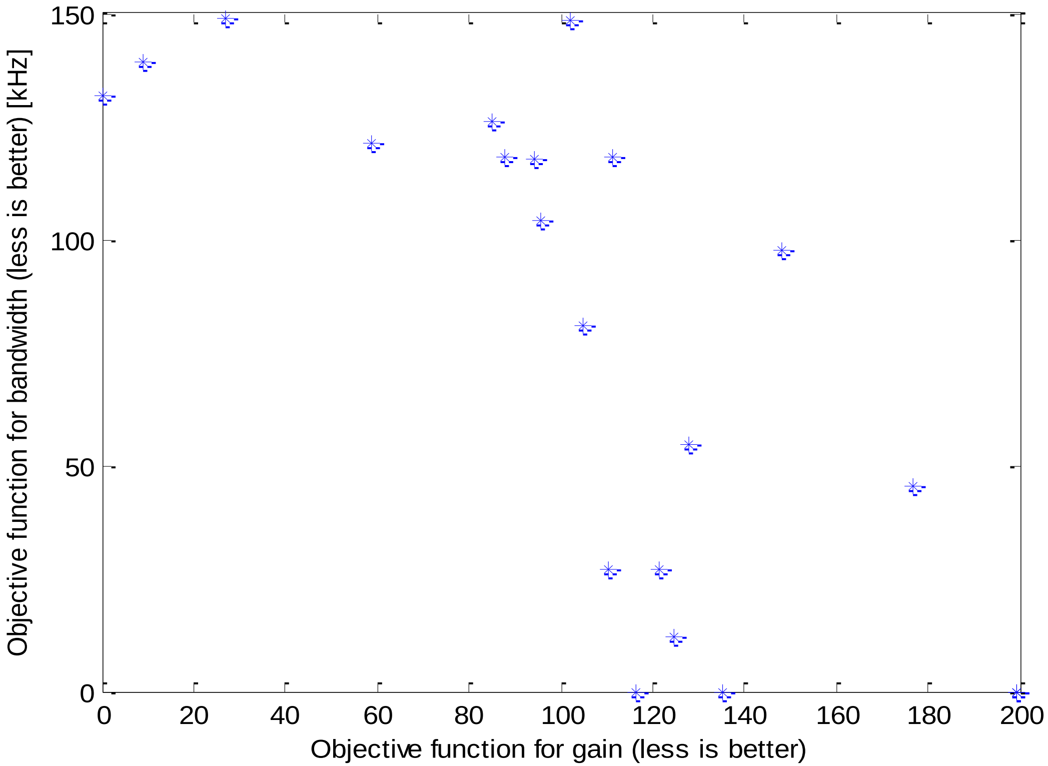
- 60 individuals, 100 generations
- 21 individuals on the final Pareto front



Rank histogram for the final Pareto front

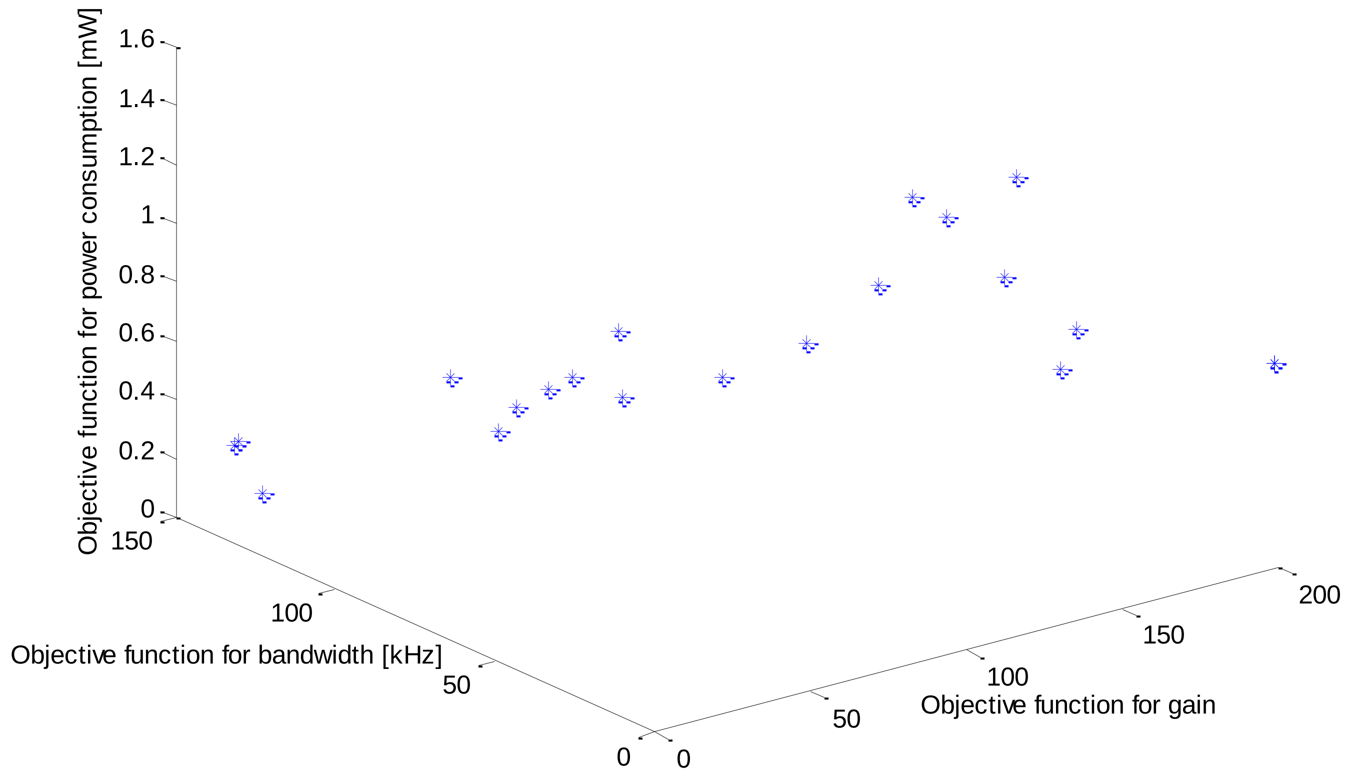
Simulations and results

Results – Bandwidth vs. Gain



Trade-off between bandwidth and gain

Simulations and results
Results – Gain vs. Bandwidth vs. Power consumption



3D plot for gain, bandwidth and power consumption

Conclusions and future development

- design illustration of a multiobjective optimization method
- “greater than” and “minimum” type design specifications
- Matlab/Spice based implementation
- solutions located on the Pareto front

☹ time consuming
☺ modular structure
☺ the designer makes the final choice

- adjustments and testing on more complex circuits