Experimental Verification of Improved Nagata Current Mirrors

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1.Objective

Most analog ICs require

reference current/voltage source

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Stable against PVT variation

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P : Process

V : Supply voltage

T : Temperature

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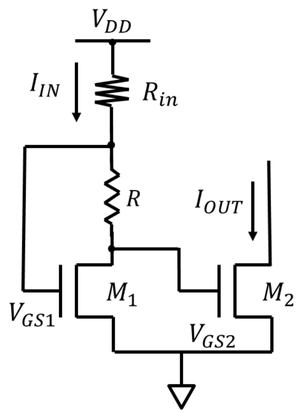
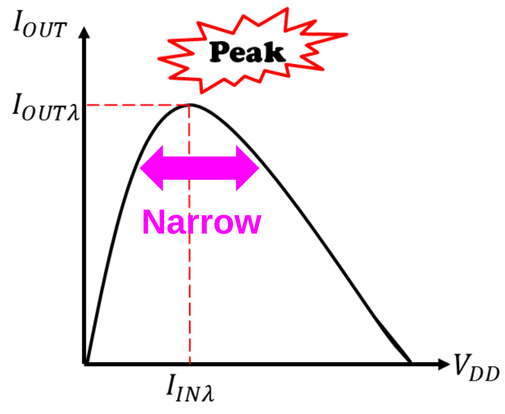
Focus on supply voltage (V)

2.Background

Original Nagata Current Mirror Circuit



MOS Nagata Current Mirror Circuit

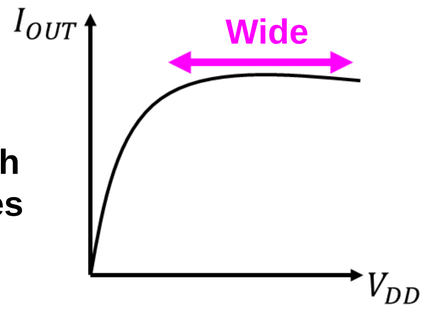


Peaking current characteristics

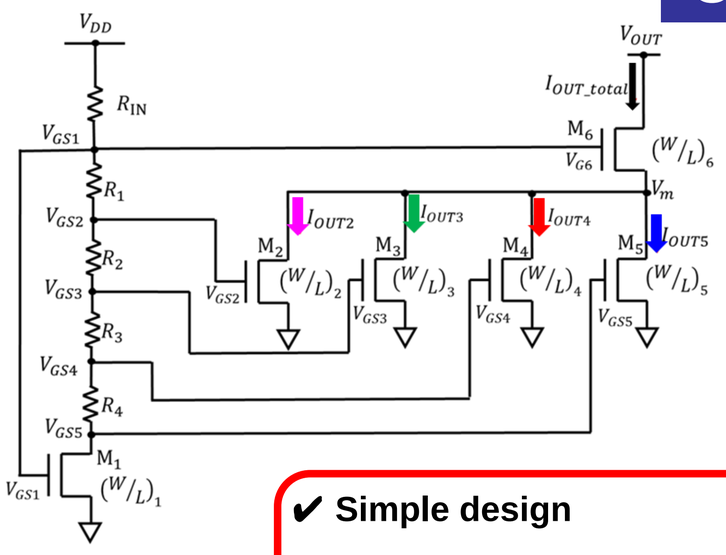
- ✔ Simple
- ✔ Constant current for supply voltage variations
- ✔ Widely used in analog ICs
- ✔ Peak vicinity is very narrow

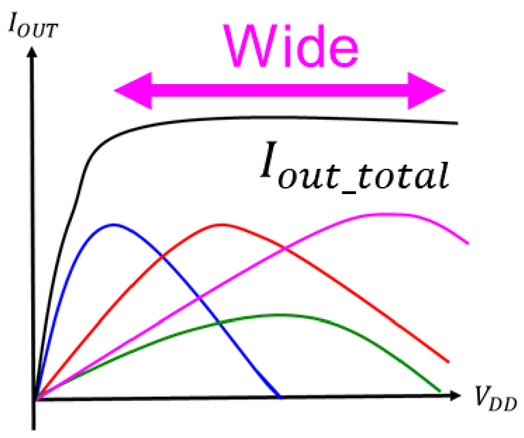
Room for improvement :

Increase the range in which the output current becomes constant



3.Proposed Circuit





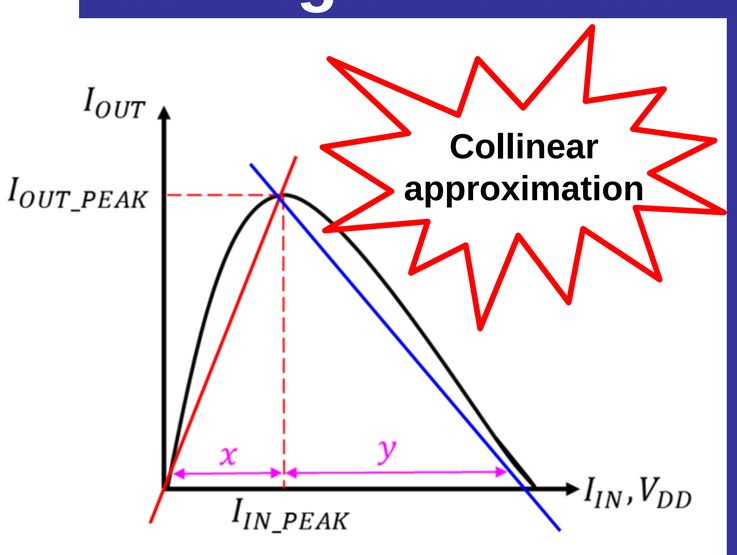
- ✔ Simple design
- ✔ Using multiple current mirror circuit with different current peaks

4.Design Guideline

- $x = 0 \sim I_{IN\_PEAK} = \dfrac{1}{4R^2K_1}$
- $y = I_{IN\_PEAK} \sim I'_{IN} = I'_{IN} - x = \dfrac{1}{R^2K_1} - \dfrac{1}{4R^2K_1} = 3x$

$\boldsymbol{x : y = 1 : 3}$

→ Establish design guideline using this ratio



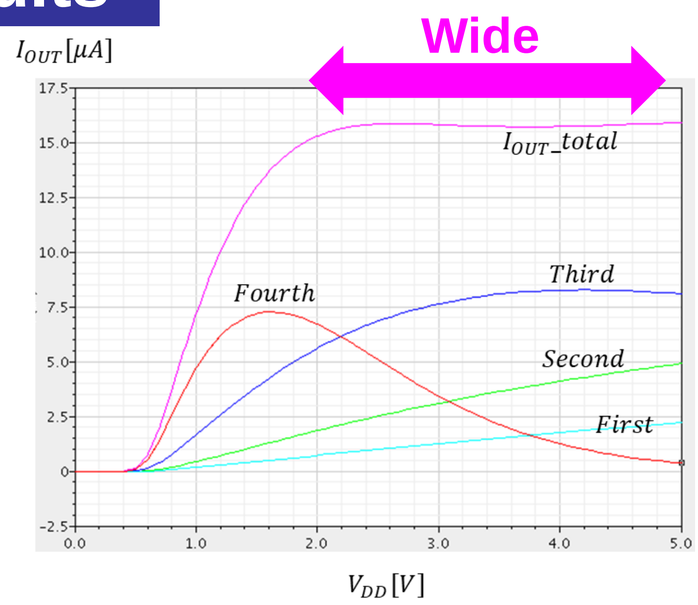
5.Simulation Results

Parameters

$W_1[\mu m]$	1.5	$R_1[k\Omega]$	3.2
$W_2[\mu m]$	0.42	$R_2[k\Omega]$	3.2
$W_3[\mu m]$	1.7	$R_3[k\Omega]$	6.4
$W_4[\mu m]$	6.8	$R_4[k\Omega]$	22.4
$W_5[\mu m]$	25.5	$R_{IN}[k\Omega]$	400
$W_6[\mu m]$	25.5		

$L = 0.35[\mu m]$ in all cases

TSMC $0.35[\mu m]$ CMOS



SPICE simulation result

6.Fabricated Chip

- 5 chips (#1, … , #5)
- 4 sets (A, … , D) per one chip
- 5 circuit (T1, … , T5) per one side

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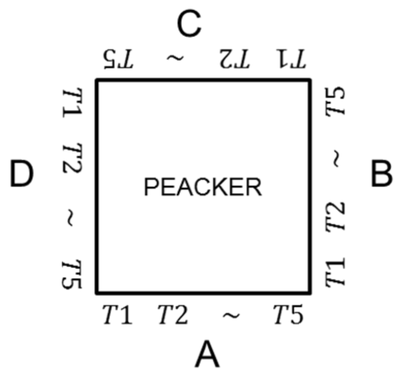
20 samples per circuit type

Measurement method

- ✔ Output voltage $V_{OUT} = 1V, 2V, 3V$
- ✔ Input voltage $V_{IN} = 0 \sim 5.0V$

→ Measured the total output current



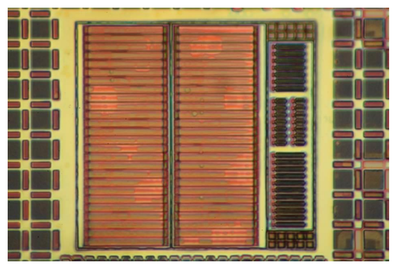
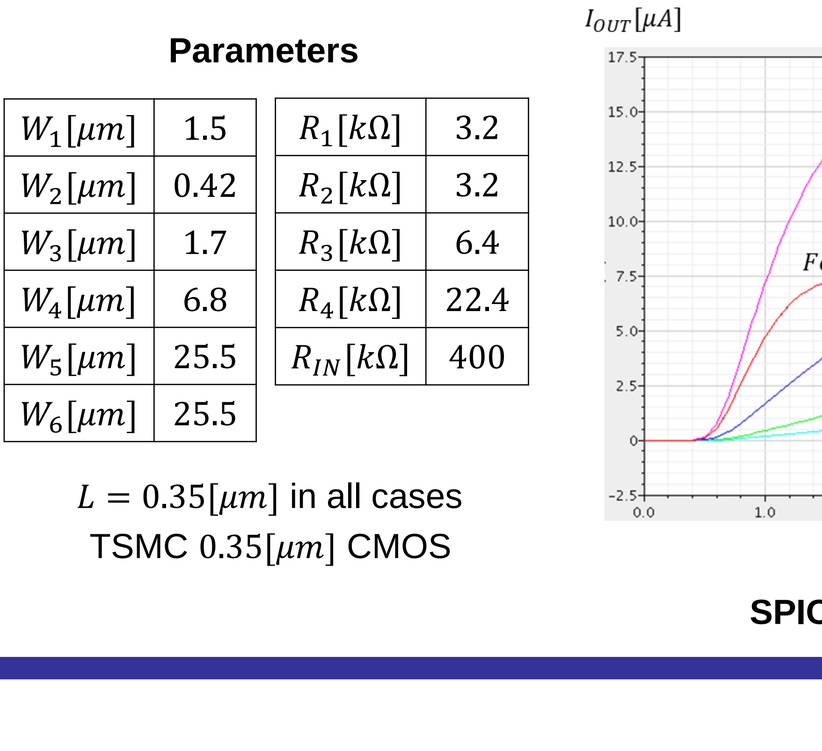


Photo of prototype chip

7.Measurement Results

I_{OUT} measurement results (#1)



I_{OUT} measurement results (side A)

- ・Fairly constant with the input voltage from 2 to 5V
- ・The variation is relatively small for T2 and T3

8.Conclusion

< Reference current source >

Conventional : Peak vicinity is very narrow

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Proposed :

Using multiple current mirror circuit with different peaks

- ✔ Simple
- ✔ Fairly stable current reference
- ✔ insensitive to wide range of power supply voltage variation

Reference

[1]M. Hirano, N. Tsukiji, H. Kobayashi, "Simple Reference Current Source Insensitive to Power Supply Voltage Variation - Improved Minoru Nagata Current Source", IEEE 13th International Conference on Solid-State and Integrated Circuit Technology, Hangzhou, China (Oct. 2016).