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Design of current Mirror and Temperature Effect with Compensation technique

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Abstract - The paper intends to reduce the temperature of current mirror , the design of current mirror and temperature effect with compensation technique. In present day high performance analog digital and power electronics systems, such as cell phone, FPGA and other digital and analog circuits it required stable current reference for proper operation. A reliable current mirror should be dependent of temperature, supply voltage[12] and process variation is necessary. Here the first order temperature compensation is to add proportional to absolute temp (PTAT) current with an inversely proportional to absolute temperature (ITAT) current. In this the current which is obtained could slow a much slower variation compared to original PTAT or ITAT current. Temperature dependent analysis to achieve better performance by reducing the temperature using compensation technique has been carried out[12]. In many analog circuit applications, The performance of the current mirror focuses on the high accuracy, high out put impedance, wide output voltage range, wide current range and fast current switching time[9].

INTRODUCTION

A current mirror replicates the input current of a current sink or current source as an output current. The output current may be identical to the input current or can be a scaled version of it. *A* current mirror is a circuit designed to copy a current through one active device by controlling the current in another active device of a circuit, keeping the output current constant regardless of loading.

The current being 'copied' can be, and sometimes is, a varying signal current. Conceptually, an ideal current mirror is simply an ideal inverting current amplifier that reverses the current direction as well or it is a current-controlled current source (CCCS). The current mirror is used to provide bias currents and active loads to circuits... *Mirror characteristics* There are three main specifications that characterize a current mirror.The first is the transfer ratio (in the case of a current amplifier) or the output current magnitude (in the case of a constant current source CCS).The second is its AC output resistance, which determines how much the output current varies with the voltage applied to the mirror.The third specification is the minimum voltage drop across the output part of the mirror necessary to make it work properly.This minimum voltage is dictated by the need to keep the output transistor of the mirror in active mode. The range of voltages where the mirror works is called the compliance range and the voltage marking the boundary between good and bad behavior is called the compliance voltage.

KEY WORD:MOSFET ,CURRENT MIRROR, COMPANSATION TECHNIC.

Temperature dependency

The temperature dependency analysis gives us relation between Iout and temperature.

For a MOSFET the temperature dependent parameters are:

1. Mobility (μ(T))
2. Threshold Voltage(Vi(T))

Mobility and threshold voltage depends on temperature according to following relations:

$\mu(T) = \mu(T_0)^{-3/2}$

$V_{t(T)} = Vt(T_o) - \alpha(T - T_o)$

Where

$\mu(T_0) = 400\ cm^2\ V^{-1} S^{-1}$ and $\alpha = 2.3\ mV/^0C$

Temperature compensation technique

The variations of a current shown to the absolute temperature can be classified into two broad categories:

1. Proportional to absolute temperature (PTAT)
2. Inversely proportional to absolute temperature (ITAT)

The basic idea to have a first order temperature compensation is to add a PTAT current with an ITAT current. This way, the current which is obtained would show a much slower variation compared to the original PTAT or ITAT currents.The individual currents are generated by using a self-biased feedback loop. The circuit used in both the loops is the same but the two loops have been designed to give opposite temperature coefficients of current. After obtaining these PTAT and ITAT currents we add both these currents to obtain a fairly constant current with respect to temperature variations.

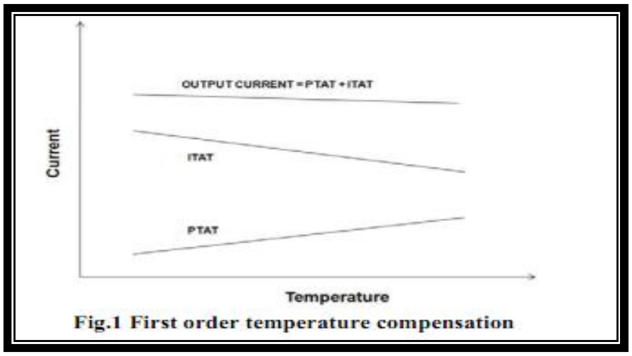


Fig.1 First order temperature compensation

Fig.1 shows the idea of this first order temperature compensation.

Specifications

- I_d =20 µA Vdd, Vgs = 1.5V
- R1=10KΩ R2=10 KΩ,
- 15 KΩ,20 KΩ
- R01=10 KΩ
- R02=0KΩ

Model parameter

- V_{gs} = 1.5V
- K'_N = 24.0 µA/V^2
- K'_P =8.0 µA/V^2
- V_{TN} =-V_{TP} = 0.75 V
- λ_N =0.01/V
- λ_P =0.02/V

simple C.M aspect ratio

By applying the model parameters values, we get :
S ≈ 2.96
=>S = 3

T-spice coding for simple C.M **:**

```
vdd 1 2 dc 1.5v
vgnd 2 0 dc 0v
M1 1 1 2 2 nmos1 w=3u l=1u
M2 3 1 2 2 nmos1 w=3u l=1u
R 1 3 10k
.MODEL NMOS1 NMOS VTO=0.75 KP=24U LAMBDA=0.01
.DC VDD 0V 1.5V 0.01V
.temp 0 27 75
.PRINT DC ID(M2), id(m1)
.OP
.END
```

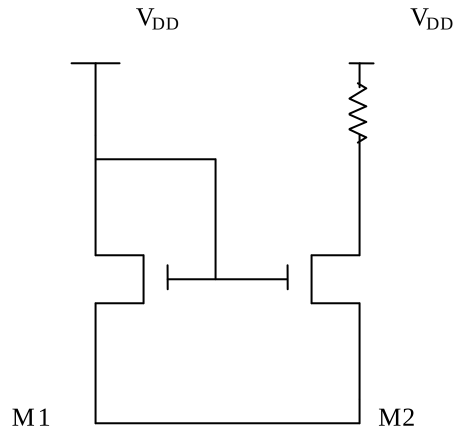


Fig2: simple Current Mirror

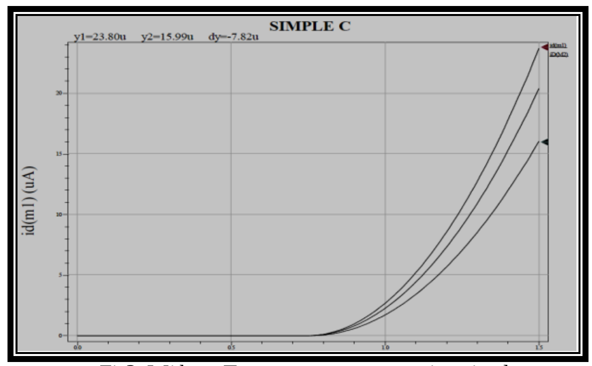
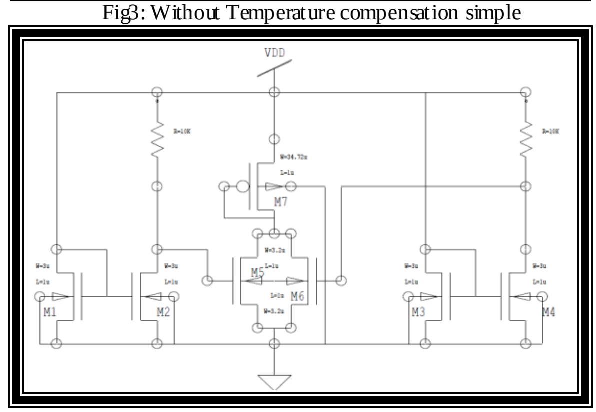


Fig3: Without Temperature compensation simple



Aspect ratio calculations

By applying the model parameters values, we get:
S =2.96
S=3=>s1=s2=s3=s4

For M_5:
When R1= R2 = 10K
Vds(M2) =1.26V

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Vgs(M5) =1.26V $I_d = \frac{K_n S}{2}(Vgs - Vt)$

By putting the values we get,

$\underline{S_5 = 3.2}$

Similarly For M_6:

Case 1: when R=10K

$\underline{S_6 = 3.2}$

Case 2: when R=15K

Vgs(M6) =1.1455V

=> $\underline{S_6 = 5.32}$

Case 3: when R=20K

Vgs(M6) =1.089V

=>$\underline{S_6 = 7.25}$

For M_7:

Vds(M5) = Vgs - Vt = 0.51

Vg(M5) = 0.51

Vsg(M5) = Vs – Vg = 1.5 – 0.51

Vsg=.99v

putting these values in saturation drain current equation.

we get,S7=34.72

3) R2= 20K

```
VDD 1 2 DC 1.5V
VGND 2 0 DC 0V
M1 1 1 2 2 NMOS1 W=3U L=1U
M2 3 1 2 2 NMOS1 W=3U L=1U
M3 1 1 2 2 NMOS1 W=3U L=1U
M4 5 1 2 2 NMOS1 W=3U L=1U
M5 4 3 2 2 NMOS1 W=3.2U L=1U
M6 4 5 2 2 NMOS1 W=7.25U L=1U
M7 4 4 1 1 PMOS1 W=34.7U L=1U
R1 1 3 10K
R2 1 5 20K
.MODEL NMOS1 NMOS VTO=0.75 KN=24U LAMBDA=0.01
.MODEL PMOS1 PMOS VTO=-0.75 KN=8U LAMBDA=0.02
.DC VDD 0 1.5V 0.01V
.TEMP 0 27 75
.PRINT DC ID(M7)
.END
```

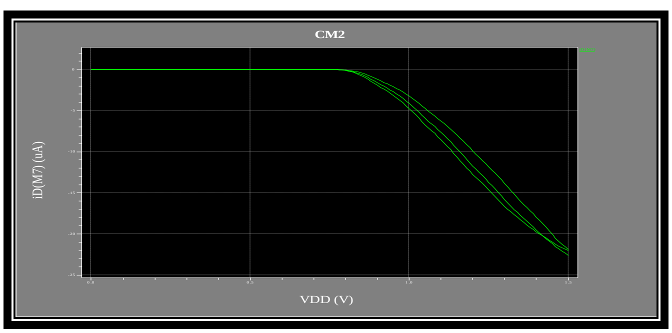

Fig 5. Without Temperature compensation

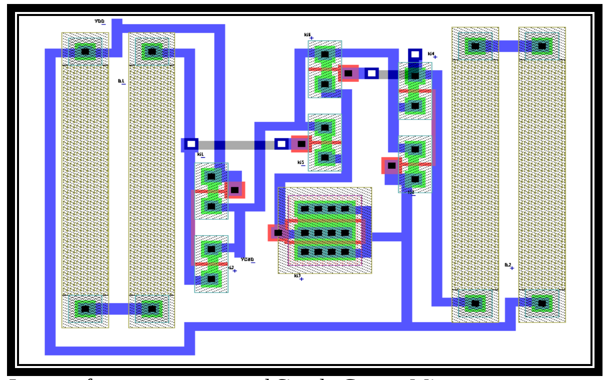

Fig 6. Layout of temp. compensated Simple Current Mirror

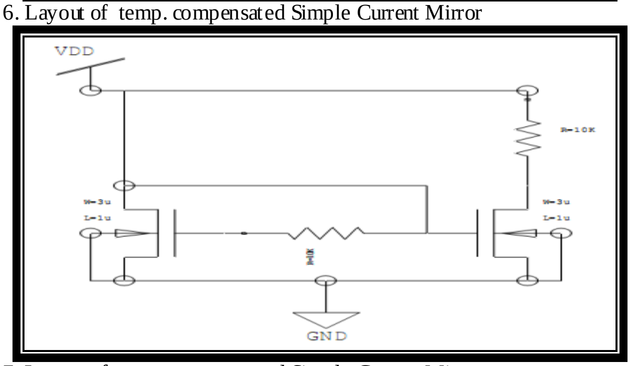

Fig 7. Layout of temp. compensated Simple Current Mirror

```
VGND 2 0 DC 0V
 M1 1 3 2 2 NMOS1 W=3.5U L=1U
 M2 4 1 2 2 NMOS1 W=3.5U L=1U
 R01 1 3 10K
 R1 1 4 10K
.MODEL NMOS1 NMOS VTO=0.75 KN=24U LAMBDA=0.01
.DC VDD 0V 1.5V 0.01V
.TEMP 0 27 75
.PRINT DC ID(M2)
.OP
.END
```

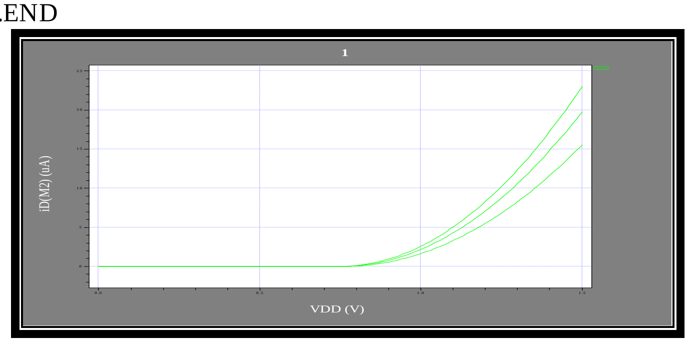

Fig8.Without Temperature compensation

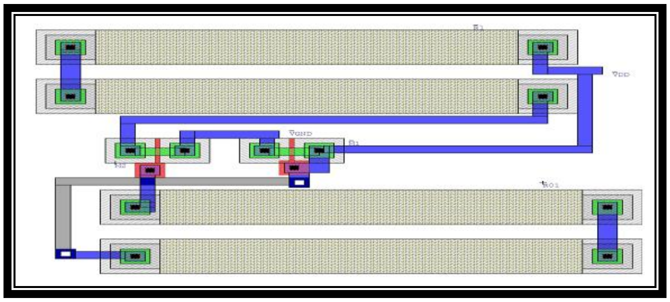

Fig 9. Layout of Modified Current Mirror

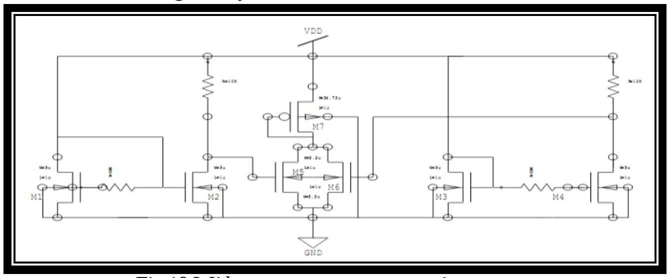

Fig 10 With temperature compensation

Aspect ratio calculation

1). Aspect Ratio

$$I_d = \frac{K_n' W \left(V_{gs} - V_t\right)^2}{2L}$$

By applying the model parameters values, we get :
S=2.96
=>S=3
=>S1=S2=S3=S4

For M_5:
When
R1= R2 = 10K
Vds(M2) =1.26V
Vgs(M5) =1.26V
By putting the values we get,
$\underline{S_5 = 3.2}$

Similarly For M_6:
Case 1: when R=10K
$\underline{S_6 = 3.2}$
Case 2: when R=15K
Vgs(M6) =1.1455V
S6=5.32
Case 2: when R=20K
Vgs(M6) =1.089V
S6=7.25

For M_7:
Vds(M5) = Vgs - Vt = 0.51
Vg(M5) = 0.51
Vsg(M5) = Vs – Vg = 1.5 – 0.51
Vsg=.99v

putting these values in saturation drain current
S7=34.72
3) R2=20K

```
VDD 1 2 DC 1.5V
VGND 2 0 DC 0V
M1 1 3 2 2 NMOS1 W=3U L=1U
M2 4 1 2 2 NMOS1 W=3U L=1U
M3 1 7 2 2 NMOS1 W=3U L=1U
M4 6 1 2 2 NMOS1 W=3U L=1U
M5 5 4 2 2 NMOS1 W=3.2U L=1U
M6 5 6 2 2 NMOS1 W=7.25U L=1U
M7 5 5 1 1 PMOS1 W=34.7U L=1U
R01 1 3 10K
R02 1 7 10K
R1 1 4 10K
R2 1 6 20K
.MODEL NMOS1 NMOS VTO=0.75 KN=24U LAMBDA=0.01
.MODEL PMOS1 PMOS VTO=-0.75 KN=8U LAMBDA=0.02
.DC VDD 0 1.5V 0.01V
.TEMP 0 27 75
.PRINT DC ID(M7)
.END
```

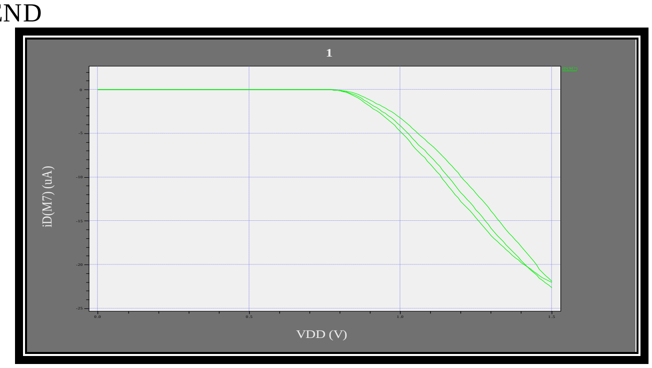

Fig11. With Temperature compensation technique R=20k

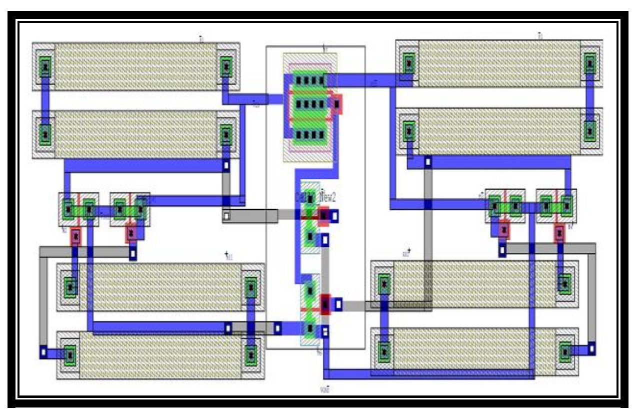

Fig12 Layout of Temperature Compensated Modified CM

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A. *Simple current mirror*

1) *Without compensation technique*

A) Without compensation technique

INPUT CURRENT	ΔIout1 ΔT=27'c	ΔIout2 ΔT=75'c
20 uA	3.35 Ua	7.68 uA

B) With compensation technique

Input Current	ΔIout1 ΔT=27	ΔIout2 ΔT=75	R1	R2	(w/l)Of M6
1.20uA	1.73	4.57	10	10	3.2
2. 20uA	0.59	2.64	10	15	5.32
3. 20uA	0.78	.78	10	20	7.25

C) Modified current Mirror

INPUT CURRENT	ΔIout1 ΔT=27'c	ΔIout2 ΔT=75'c
20 uA	4.35 Ua	7.44 uA

D) Modified current Mirror

Input Current	ΔIout1 ΔT=27	ΔIout2 ΔT=75	R1	R2	(w/l)Of M6
1.20uA	1.53	4.45	10	10	3.2
2. 20uA	2.63	0.64	10	15	5.32
3. 20uA	0.499	0.499	10	20	7.25

CONCLUSION

The T-spice simulation and layout of compensated simple current mirror and modified current mirror were successfully designed and tested under the specification of 20uA current.

The result obtained is fairly desirable as follows:

1.For simple current mirror without temperature compensation:

With the change in temperature from 0-25'C the current has a variation of 3.56 uA.And with further change in temperature from 0-75'C the current has a variation of 7.44 uA.

With the use of temperature compensation technique, the current variation for simple current mirror in 0-25'C and 0-75'C scale has been reduced to .78 uA which proves the fact that temperature compensation technique has a constant output current irrespective of change in the temperature.

Similarly in Temperature compensated modified current mirror the current variation has been reduced to .499 uA with the temperature variations of 0-25'C and 0-75'C.

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