EFFECT OF MOSFET ASPECT RATIO ON CURRENT MIRROR USING DIFFERENT CURRENT SOURCES

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Abstract

A highly efficient current mirror circuit is the need of every analog integrated circuits. They are mainly used to bias amplifier stages in analog ICs. Current mirror circuit should provide constant, predictable and precise current. In order to do so reference current given to current mirror should be constant, predictable and precise. Objective of this paper is to discuss the various reference current generation schemes and their dependency on the Aspect Ratio of Current Mirror's MOSFET. Current mirror circuit with Resistor based and MOSFET based reference current generation schemes is implemented in this paper and simulated for different values of Aspect Ratio of current Mirror's MOSFET. Effect of change in Aspect Ratio of current mirror's MOSFET on reference current value is compared for different current generation schemes to find which current generation scheme is more suitable for current mirror circuit using MOSFET.

Keywords:

Current Mirror, Aspect Ratio, Reference Current, Current Generation Schemes

1. INTRODUCTION

Current Sources are mainly used to bias the integrated Circuits. A single IC chip consist a number of amplifier stages that need to be bias with Constant, Predictable and Precise Current Source. Constant dc current is generated at one location which is also known as a reference current and then replicate the same by the process known as current steering or current mirroring at various other locations for the purpose of biasing the various amplifier stages. This approach avoids the efforts of generating a new predictable and stable reference current, usually utilizing a precision resistor external to the chip, need not be repeated for every amplifier stage [1]-[3].

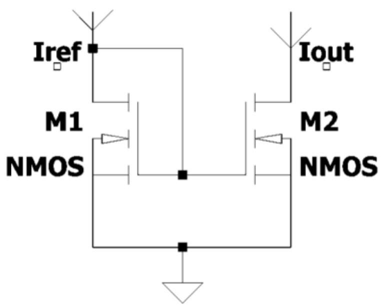

Fig.1. Structure of Basic Current Mirror

Current mirror circuits are used to copying currents from reference currents to generate multiple Current Sources in analog circuits. It is desired to have one Precisely-defined current source for current mirroring process. Basic current mirror is simply designed by using two MOSFETs connected in specific way as shown in Fig.2. Current Mirror circuit could be further modified to give high internal resistance and to avoid the channel length modulation effect of MOSFETs [6]-[12].

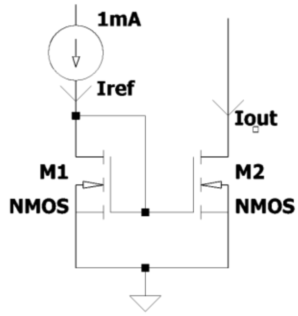

Fig.2. Basic Current Mirror Circuit Using MOSFET

Current mirrors using MOSFETs as shown in Fig.1 have been widely used in analog integrated circuits for biasing amplifiers as well as for active load consideration. MOSFETs of current mirror circuit M_1 and M_2 shown in Fig.1 consists identical parameters and characteristics, i.e. value of V_{Tn} and K_n is assumed to be same for both MOSFETs M_1 and M_2. This circuit is basically designed to provide $I_{out}=I_{REF}$, where I_{REF} is reference current provides biasing current to the circuit and Iout is the output current of the circuit. Since the basic need of this circuit is mirroring the reference current to the output current, therefore the circuit known as "current mirror" [4]-[5]

2. DESIGN OF CURRENT MIRROR CIRCUIT

Purpose of current mirror circuit is to either copy the same reference current or modified its value as per the biasing requirement of amplifier stages.

From Fig.2, it is seen that both MOSFETs M_1 and M_2 are biased with same gate to source voltage $V_{GS,}$ such that both the MOSFET should work under saturation region so that output current remains constant.

Equations of reference and output current for the MOSFETs M_1 and M_2 working under saturation region can be given as,

$$I_{out}=I_{D2}=0.5\mu_n Cox\left(\frac{W}{L}\right)_2\left(V_{GS}-V_T\right)^2\left(1+\lambda V_{DS2}\right) \tag{1}$$

$$I_{REF}=I_{D1}=0.5\mu_n Cox\left(\frac{W}{L}\right)_1\left(V_{GS}-V_T\right)^2\left(1+\lambda V_{DS1}\right) \tag{2}$$

where, $\left(\frac{W}{L}\right)$ is called as Aspect Ratio of MOSFET and λ is Channel Length Modulation Coefficient.

Eq.(1) and Eq.(2) shows that reference current and output current is depend on Aspect Ratio of MOSFET as well as Channel length Modulation coefficient. If Aspect Ratio changes it cause proportional change in reference current and output current. Similarly, both the current is also depending on V_{DS} due to channel length modulation effect.

Neglecting Channel length modulation effect,

$$I_{out} = I_{D2} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_2 (V_{GS} - V_T)^2 \quad (3)$$

$$I_{REF} = I_{D1} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_1 (V_{GS} - V_T)^2 \quad (4)$$

Hence,

$$I_{out} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1} I_{REF} \quad (5)$$

From the above relation shown in Eq.(5), it is observed that output current of current mirror I_{out} is only depending upon Aspect Ratio of each MOSFET and value of reference current I_{REF}. If Aspect Ratio of both the MOSFETs kept same i.e. $(W/L)_1 = (W/L)_2$ then output current is equal to reference current i.e. $I_{out}=I_{REF}$.

From the above discussion it is seen that $I_{out}=I_{REF}$, if $(W/L)_1 = (W/L)_2$. But value of reference current I_{REF} also depends on value of Aspect Ratio of current mirror's MOSFET M_1 as shown in Eq.(2). Therefore, changing Aspect Ratio (W/L) of current mirror's MOSFETs also changes the values of reference current and henceforth output current even though $(W/L)_1=(W/L)_2$. Effect of change in Aspect Ratio is different for different current generation scheme. In next section reference current for current mirror circuit is implemented by resistor based and effect of change in Aspect Ratio of current mirror MOSFETs is observed.

3. IMPLEMENTATION OF CURRENT MIRROR CIRCUIT USING VARIOUS CURRENT SOURCES

In every current mirror circuit, generation of reference current plays vital role. In this work current mirror circuit with four types of reference current generation scheme is implemented and effect of change in Aspect Ratio of current mirror's MOSFET on the value of reference current is observed. Four different reference current generation schemes which is considered under this section are,

- Ideal Current Source
- Resistor Based Current source (for high value of I_{REF})
- MOSFET Based Current Source
- Resistor Based Current source (for low value of I_{REF})

3.1 CURRENT MIRROR CIRCUIT WITH IDEAL CURRENT SOURCE

Current Mirror circuit employing Ideal current Source is been implemented as shown in Fig.3. Ideal Current source of 1mA is considered for simulation purpose. Effect of change in Aspect Ratio of MOSFETs on reference current is been observed.

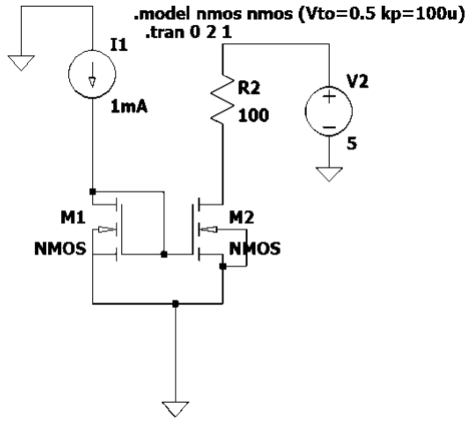

Fig.3. Current Mirror Circuit with Ideal Current Source

3.2 CURRENT MIRROR USING RESISTOR BASED CURRENT SOURCE (FOR HIGH VALUE OF *I*I_{REF})

Current mirror circuit using resistor based Current source is been implemented as shown in Fig.4. Current source has been designed for high value of reference current I_{REF} = 0.83 mA. Aspect Ratio of current mirror's MOSFET M_1 is considered as 1, value of K_n' is 100µA/V^2 and V_{Tn} = 0.5V for the designing of reference current source shown in Fig.4.

From the circuit shown in Fig.4,

$$\because I_{REF} = I_{D1}$$

$$\frac{V_{DD} - V_{GS}}{R} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_1 (V_{GS} - V_T)^2 \quad (6)$$

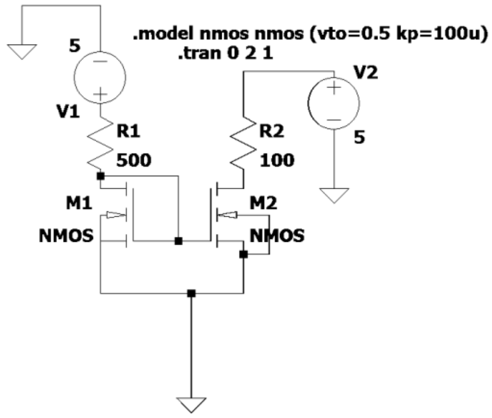

Fig.4. Current Mirror using Resistor Based Current source (for high value of IREF)

The Eq.(6) clearly states that reference current value is depend on the value of Resistance R as well as value of Aspect Ratio (W/L) of current Mirror's MOSFET. In this case the value of resistance R is low for high value of I_{REF} and the effect of change in Aspect ratio value on reference current variation is observed.

3.3 CURRENT MIRROR CIRCUIT WITH MOSFET BASED CURRENT SOURCE

Another approach of generating reference Current is building current source using MOSFET. MOSFET under saturation works as a constant current source, whose current value can be decided by selecting proper biasing voltage V_3 as shown in Fig.5.

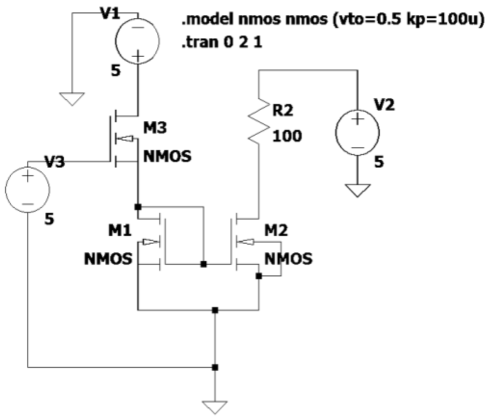

Fig.5. Current Mirror Circuit with MOSFET Based Current Source

Current through M_3 would be given by,

$$I_{REF} = I_{D3} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_3 (V_{GS3} - V_{T3})^2 \quad (7)$$

Current through M_1 and M_3 are equal as they are in series:

$$I_{REF} = I_{D3} = I_{D1} \quad (8)$$

$$I_{REF} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_1 (V_{GS1} - V_{T1})^2 = 0.5\mu_n Cox\left(\frac{W}{L}\right)_3 (V_{GS3} - V_{T3})^2 \quad (9)$$

The Eq.(9) shows that reference current in MOSFET based reference current source is depend on Aspect Ratio of MOSFET M_3 as well as current mirror's MOSFET M_1.

3.4 CURRENT MIRROR USING RESISTOR BASED CURRENT SOURCE (FOR LOW VALUE OF I_{REF})

Current mirror circuit using resistor based Current source for low value of reference current is been implemented as shown in Fig.6. Current source has been designed for I_{REF} = 36 µA considering Aspect Ratio of current mirror's MOSFET equal to 1.

$$\because I_{REF} = I_{D1}$$

$$\therefore \frac{V_{DD} - V_{GS}}{R} = 0.5\mu_n Cox\left(\frac{W}{L}\right)_1 (V_{GS} - V_T)^2 \quad (6)$$

Reference current value is depending on the value of Resistance R as well as value of aspect Ratio of current Mirror's MOSFET. In this case the value of resistance R is high for low value of I_{REF} and the effect of change in Aspect ratio value on reference current variation is observed.

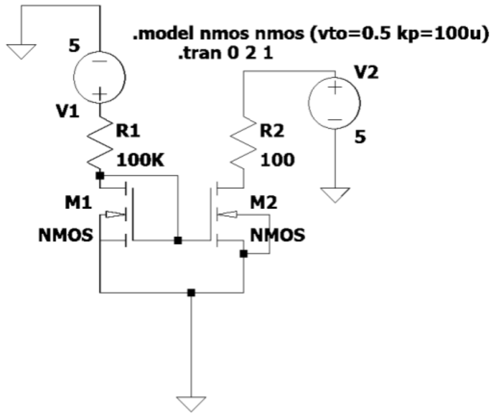

Fig.6. Current Mirror using Resistor Based Current source (for low value of IREF)

4. RESULTS AND DISCUSSION

Current Mirror circuit with four different reference current generating circuit is implemented and simulated in previous section. All the four current mirror circuits with different reference current generation scheme is simulated for three different values of Aspect Ratio of Current Mirror's MOSFET, $(W/L)_1=(W/L)_2=0.5$, $(W/L)_1=(W/L)_2=1$ and $(W/L)_1=(W/L)_2=1.5$. Effects of change in Aspect Ratio of Current Mirror's MOSFET on reference current is been observed as shown below.

4.1 CURRENT MIRROR CIRCUIT WITH IDEAL CURRENT SOURCE

Case 1: In this case W and L of both MOSFET are kept at 0.5µm and 1µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=0.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same as ideal current source value i.e. 1 mA as shown in Fig.7.

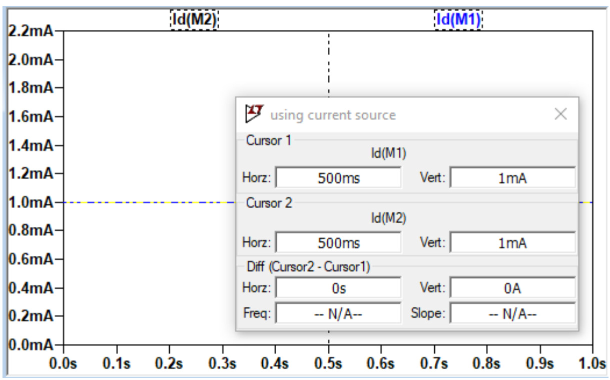

Fig.7. Result for I_{out} and I_{REF} for Aspect Ratio = 0.5

Case 2: In this case W and L of Both MOSFET are kept at 1µm. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains again same as ideal current source value i.e. 1 mA as shown in Fig.8.

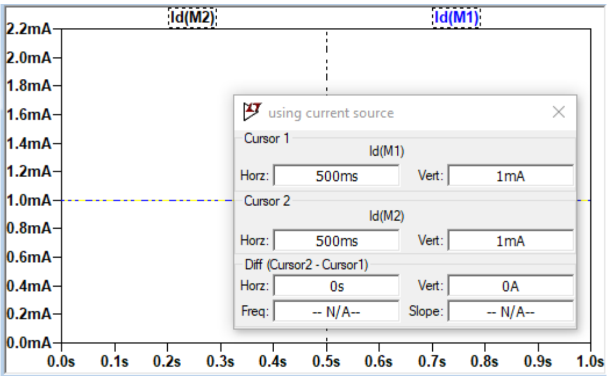

Fig.8. Result for I_{out} and I_{REF} for Aspect Ratio = 1

Case 3: In this case *W* and *L* of Both MOSFET are kept at 1.5 µm and 1 µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains again same as ideal current source value i.e. 1 mA as shown in Fig.9.

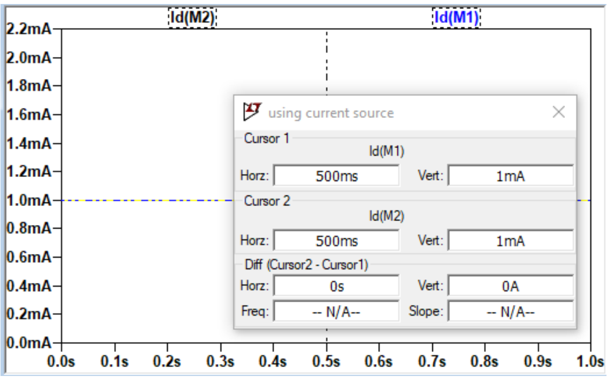

Fig.9. Result for I_{out} and I_{REF} for Aspect Ratio = 1.5

From the above three cases, it is observed that if ideal current source is considered for reference current then value of output current and reference current remains constant irrespective of change in Aspect ratio value.

4.2 CURRENT MIRROR USING RESISTOR BASED CURRENT SOURCE (FOR HIGH VALUE OF I_{REF})

Case 1: In this case *W* and *L* of Both MOSFET are kept at 1µm. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same as designed value i.e. 0.833 mA as shown in Fig.10.

Case 2: In this case *W* and *L* of both MOSFET are kept at 0.5µm and 1µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=0.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same but value is changed to 456.2µA from 833.6µA as shown in Fig.11.

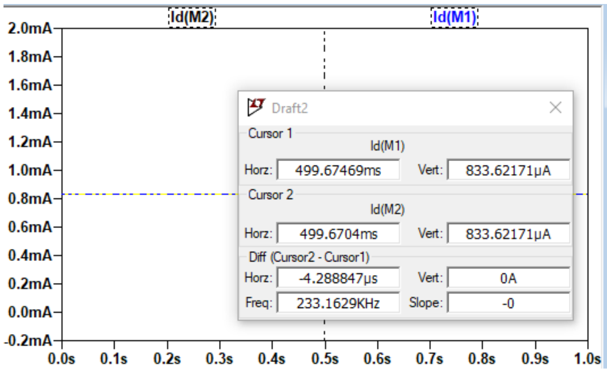

Fig.10. Result for I_{out} and I_{REF} for Aspect Ratio = 1

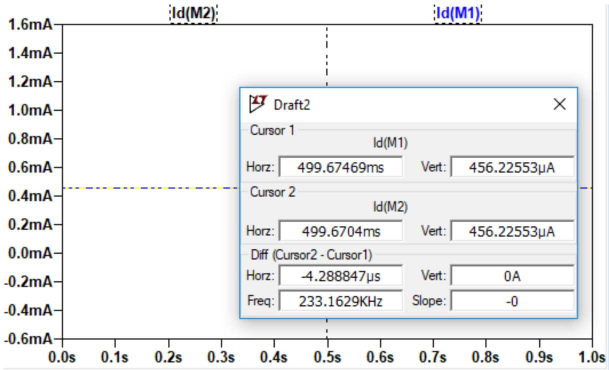

Fig.11.Result for I_{out} and I_{REF} for Aspect Ratio = 0.5

Case 3: In this case *W* and *L* of Both MOSFET are kept at 1.5 µm and 1 µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same but value is again changed to 1.15mA from 833.6µA for increment of 0.5 in Aspect Ratio value as shown in Fig.12.

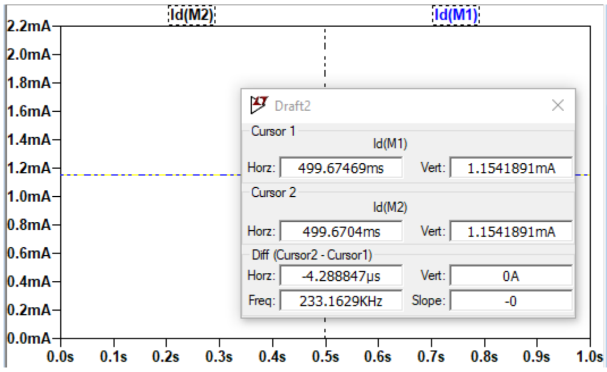

Fig.12. Result for I_{out} and I_{REF} for Aspect Ratio = 1.5

From the above three cases it is observed that if current source is resistor based for reference current then value of output current and reference current changes due to change in Aspect ratio value. Change in reference current is seem to be high in this case when value of resistor is low for high value of reference current.

4.3 CURRENT MIRROR CIRCUIT WITH MOSFET BASED CURRENT SOURCE

Case 1: In this case *W* and *L* of both MOSFET are kept at 0.5µm and 1µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=0.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same at 298.2 µA as shown in Fig.13.

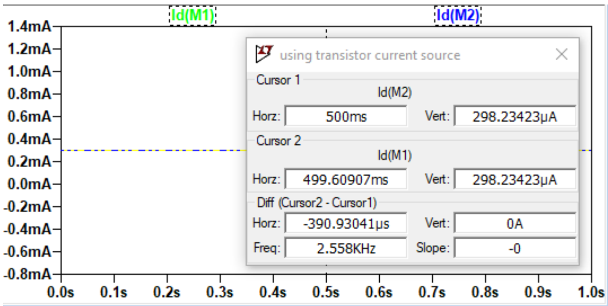

Fig.13. Result for I_{out} and I_{REF} for Aspect Ratio = 0.5

Case 2: In this case *W* and *L* of Both MOSFET are kept at 1µm. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains again same but increased to 534.3 µA as shown in Fig.14.

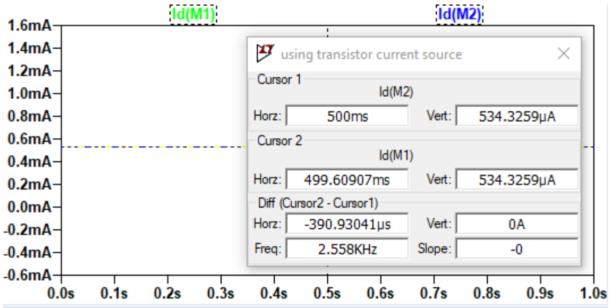

Fig.14. Result for I_{out} and I_{REF} for Aspect Ratio = 1

Case 3: In this case *W* and *L* of Both MOSFET are kept at 1.5 µm and 1 µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains exactly same but value is again changed to 739.5 µA as shown in Fig.15.

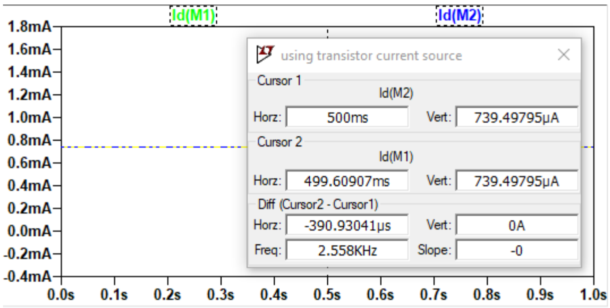

Fig.15. Result for I_{out} and I_{REF} for Aspect Ratio = 1.5

From the above three cases of MOSFET based current source it is observed that value of output current and reference current changes due to change in Aspect ratio value. For the change in Aspect Ratio of 0.5 to 1.5, reference current changed from 298.2 µA to 739.5 µA.

4.4 CURRENT MIRROR USING RESISTOR BASED CURRENT SOURCE (FOR LOW VALUE OF I_{REF})

Current Mirror using Resistor Based Current source for low value of reference current I_{REF} shown in Fig.6 is simulated for three different Aspect Ratio value of current mirror's MOSFET.

Case 1: In this case *W* and *L* of both MOSFET are kept at 0.5µm and 1µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=0.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same at 33.4 µA as shown in Fig.16.

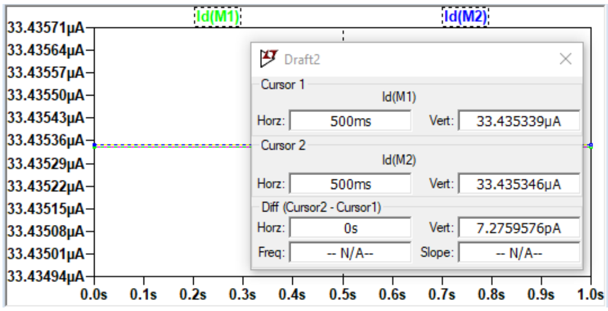

Fig.16. Result for I_{out} and I_{REF} for Aspect Ratio = 0.5

Case 2: In this case *W* and *L* of Both MOSFET are kept at 1µm. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} remains same again but slightly increased to 36.46 µA as shown in Fig.17.

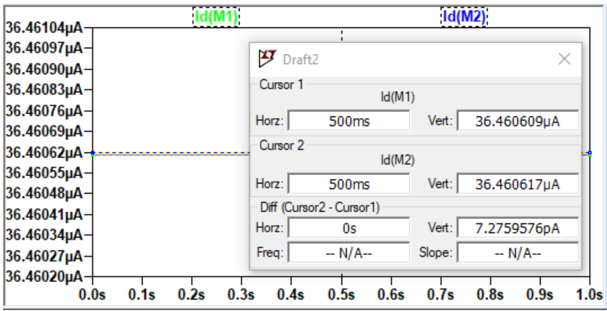

Fig.17. Result for I_{out} and I_{REF} for Aspect Ratio = 1

Case 3: In this case *W* and *L* of Both MOSFET are kept at 1.5 µm and 1 µm respectively. Therefore, Aspect Ratio value become $(W/L)_1=(W/L)_2=1.5$ for the current mirror's MOSFETs and it is observed that reference current I_{REF} and Output current I_{out} is same but it is changed to 37.9 µA as shown in Fig.18.

From the above three cases Resistor based current source for low value of reference current, it is observed that value of output current and reference current changes due to change in Aspect ratio value. But for the change in Aspect Ratio of 0.5 to 1.5, reference current changed in small value from 33.4µA to 37.9µA.

The Table.1 shows the values of reference current change due to change in Aspect Ratio value of Current Mirror's MOSFET for four different type of reference current generation scheme. As seen from Table.1, Value of I_{REF} and I_{out} is constant for Ideal

Current Source but changes drastically for resistor based and MOSFET based current source. If low value is selected for reference current source then it shows slight variation in values.

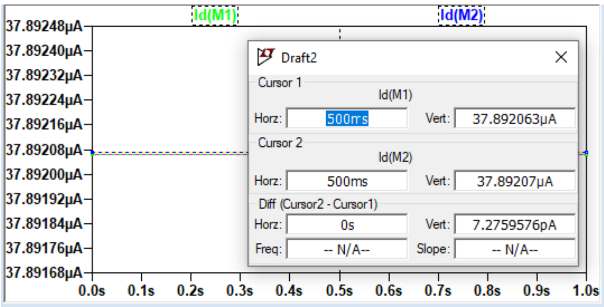

Fig.18. Result for I_{out} and I_{REF} for Aspect Ratio = 1.5

Table.1. Effect of change in Aspect Ratio of MOSFETs of Current Mirror on Reference Currents I_{REF}

	Aspect Ratio = 0.5		**Aspect Ratio = 1**		**Aspect Ratio = 1.5**	
Type of Reference Current Generation Scheme	**I_{REF} (µA)**	**I_{out} (µA)**	**I_{REF} (µA)**	**I_{out} (µA)**	**I_{REF} (µA)**	**I_{out} (µA)**
Ideal Current Source	1000	1000	1000	1000	1000	1000
Resistor Based Current source (for high value of I_{REF})	456.2	456.2	833.6	833.6	1150	1150
MOSFET Based Current Source	298.2	298.2	534.3	534.3	739.4	739.4
Resistor Based Current source (for low value of I_{REF})	33.43	33.43	36.46	36.46	37.89	37.89

5. CONCLUSION

Current mirror circuit with various types of reference current generation circuit has been implemented and simulated for different values of Aspect Ratio of MOSFETs. It is been observed that if Ideal current source is considered for reference current then irrespective of change in Aspect Ratio of MOSFETs reference current as well as output current remains constant. When same ideal current source is replaced with resister based high value current source then change in Aspect Ratio of MOSFETs cause a large deviation in the values of reference current and so output current. Same process has been repeated by replacing resister based current source with MOSFET based current source but again deviation in reference current value has been observed for change in Aspect Ratio of Current mirror's MOSFETs. But when resistor based current source for very low reference current is simulated for various Aspect Ratio of MOSFETs then deviation in reference current has been observed very low.

Hence for a current mirror circuit to perform better the value of internal resistance offered by reference current source should be ideally infinite and practically as high as possible. A reference current source with very high value of internal resistance makes reference current independent on Aspect Ratio of Current Mirror's MOSFET.

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