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Description of previous circuits and the new current mirror:-

Previous current mirror circuits:-

The traditional current mirror is shown in fig. 1. As the traditional current mirror’s output impedance is not infinite, it will influence the output current $I_{out}$ by the variation of the output node voltage $V_{ds}$. It is a drawback in the analog circuits. In fig. 2 the cascode current mirror is shown. It has the matching accuracy [7] problem and it was proposed to improve the output impedance. In fig. 3 the IAFCCM is shown. It was proposed to increase the output impedance,
output voltage swing and matching accuracy. IAFCCM improves lots of output voltage swing, but the output impedance is not high enough. Meanwhile the output node voltage influences the output current $I_{out}$.

**The proposed new current mirror circuit:**

![Fig 4: The proposed current mirror [1]](image1)

The proposed new current mirror improves the new key parameters of the current mirror, the matching accuracy and output impedance. The fig.4 shows the schematic diagram of the proposed new current mirror. Here are some MOS transistors such as M0, M2, M10 are used as a two stage cascode current mirror and some MOS transistors such as M1, M6, M9, M7 and M8 are used to improve the matching accuracy of the cascode current mirror. M3, M4 and M14 are the three novel negative feedback gain stages that can increase the output impedance of the current mirror significantly.

![Fig 5: The feedback circuit [1]](image2)

The feedback circuit of the current mirror is shown in fig.5 and the voltage gain of each gain stage is shown as $A$. The output impedance are out of the new proposed current mirror can be estimated by following.

$$V_1 = i \cdot \frac{1}{g_{d2}} \quad \text{[1]}$$

$$i = g_{m10} \cdot (\lvert A \rvert^3 - 1) \cdot V_1 + g_{d10} \cdot (V_0 - V_1) \quad \text{[2]}$$

$$=> i \cdot \left(1 + \frac{g_{m10}}{g_{d2}} \cdot \lvert A \rvert^3 + \frac{g_{m10}}{g_{d2}} + \frac{g_{d10}}{g_{d2}}\right) = g_{d10} \cdot V_0$$

$$=> \frac{V_0}{i} = \left(1 + \frac{g_{m10}}{g_{d2}} \cdot \lvert A \rvert^3 + \frac{g_{m10}}{g_{d2}} + \frac{g_{d10}}{g_{d2}}\right) + g_{d10}$$
\[ R_0 = \frac{g_{m10}}{g_{d10}} \frac{1}{g_{d2}} |A|^3 \]

\[ R_{out} = \frac{g_{m3}}{g_{d3}} \frac{1}{g_{d5}} \frac{1}{g_{d5} / g_{d5}} \]

As shown in equation (4) where A ≈ \( \frac{g_{m}}{g_{d}} \) (i.e. 3, 4 and 14 respectively), the proposed new current mirror has much larger \( R_{out} \) than that of the IAFCCM which has output impedance \( R_{out} = g_{m53} g_{m5k} \frac{1}{g_{d52}} \frac{1}{g_{d53}} \frac{1}{g_{d5k} / g_{d5k}} \).

Fig 6:- The I-V curve of the simulation result [1]

In fig.5 the voltage \( V_1 \) is independent of \( V_0 \). When \( V_0 \) and \( V_1 \) are increased then the \( V_{d14} \) is decreased due to the three gain stages. The negative feedback signal is created by connecting \( V_{d14} \) to the gate of \( M_{10} \). Therefore decrease in \( V_{d14} \) decrease the \( V_1 \). Thus the negative feedback loop locks \( V_1 \) so that a stable \( I_{out} \) is obtained. Now the proposed new current mirror has high output impedance.

For a good current mirror another factor is the matching accuracy [10] between \( I_{in} \) and \( I_{out} \). The MOS transistors \( M_6, M_7, M_8 \) and \( M_9 \) are used to match the current \( I_{ml} \) and \( I_{m2} \) in the new proposed circuit and further make \( V_{Gm1} = V_{Gm3} \). From \( V_{Gm1} = V_{Gm0} = V_{Dx0} \) and \( V_{Gm3} = V_{Dx2} \), we can find \( V_{Dx2} = V_{Dx0} \) which results \( I_{in} = I_{out} \). The proposed new current mirror has better matching accuracy than the IAFCCM and it is proved by the HSPICE simulation results.

**Simulation Results:**

The HSPICE simulation results are based upon 0.35\( \mu \)m 1P4M CMOS process which has a supply voltage of 3.3V where, \( L= 1 \mu m \) for all transistors except \( M_8, M_9 \) transistors for which \( L= 3 \mu m \). \( W= 20 \mu m \) for \( M_0, M_1, M_2, M_3, M_6, M_7, M_{10} \) and \( W= 40 \mu m \) for \( M_8, M_9 \) to ensure \( I_{out} = 100\mu A \)

\( W= 5 \mu m \) for \( M_4, M_{14} \)

\( W= 10 \mu m \) for \( M_5, M_{11} \)

\( W= 1 \mu m \) for \( M_{12}, M_{13} \)

The I-V curve simulation result of the proposed new current mirror and IAFCCM is shown in fig.6. The I-V plot of the input current \( I_{in} \) is the lowest line. The top line is the I-V plot of IAFCCM, it shows that the output impedance is not that much high to avoid the influence of \( V_{ds} \), i.e. under the variation of the output voltage \( V_0 \) the \( I_{out} \) will be changed. The I-V plot of the proposed circuit is the middle line and it indicates that the output impedance of the proposed circuit is higher than IAFCCM. In fig.6 the comparison results of the accuracy is shown. The proposed circuit has a matching accuracy better than IAFCCM when the input current \( I_{in} = 100\mu A \).
Table 1:- The proposed CM performance comparison with IAFCCM [1]

| Issue                              | The proposed circuit | IAFCCM   |
|------------------------------------|----------------------|----------|
| Mirroring error lin=5uA            | 0.016%               | 0.036%   |
| Mirroring error lin=10uA           | 0.012%               | 0.03%    |
| Mirroring error lin=100uA          | 0.001%               | 0.019%   |
| Mirroring error lin=200uA          | 0.005%               | 0.015%   |
| Mirroring error lin=400uA          | 0.012%               | 0.014%   |
| Rout                               | $\frac{1}{gd} \left( \frac{gm}{gd} \right)^2$ | $\frac{1}{gd} \left( \frac{gm}{gd} \right)^2$ |

Table 1 shows the comparison result between the proposed circuit and IAFCCM under various input circuit. Input current changes from 5µA to 400µA. When the input current is lower than 400µA due to the MOS transistor sizes of the proposed circuit are smaller than IAFCCM. But the output impedance $R_{out}$ of the proposed new circuit is larger than that of the IAFCCM.

**Conclusion:-**

A high output impedance and high accuracy current mirror is proposed and analyzed in this paper. According to the simulation results the accuracy and the output impedance of the proposed circuit is better than IAFCCM. The proposed current mirror is much suitable for using in high linearly, high output impedance current output stages and the operational amplifiers design.

**Acknowledgement:-**

The authors are thankful to Mr. Aseem Chauhan (Additional President, RBED and Chancellor AUR, Jaipur), Maj. General K. K. Ohri (AVSM, Retd.) Pro-VC, Amity University, Uttar Pradesh Lucknow, Prof. S. T. H. Abidi (Director ASET, Lucknow Campus), Brig. U. K. Chopra (Director AIIT & Dy. Director ASET), Prof O. P. Singh (HOD, Electrical & Electronics), Prof. H. K. Dwedi (Dy. Director, Research in Electronics) and Prof. N. Ram (Dy. Director ASET) for their motivation, kind cooperation, and suggestions.

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