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# SUPERIOR-ORDER CURVATURE-CORRECTED CMOS VOLTAGE REFERENCES: AN ORIGINAL APPROACH

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**Abstract**: Two CMOS voltage references with superior-order curvature-corrections will be presented. For the first circuit, the linear compensation is realized using an original $OVF$ (Offset Voltage Follower) block as $PTAT$ (ProporTional with Absolute Temperature) voltage generator, while the new logarithmic curvature-correction technique is implemented using an $ADA$ (Asymmetric Differential Amplifier) for compensating the logarithmic temperature dependent term. The reducing of the temperature coefficient for the second voltage reference is made compensating the nonlinear temperature dependence of the gate-source voltage by the difference between two other gate-source voltages.

**Key words**: curvature-correction, temperature dependence, weak inversion, PTAT.

## 1. INTRODUCTION

The reference voltage circuits find applications in A/D or D/A converters, data acquisition systems, memories or smart sensors. There will be proposed two superior-order curvature-corrected voltage references based on an Asymmetric Differential Amplifier ($ADA$) block and on the weight difference of gate-source voltages for MOS transistors working in weak inversion.

## 2. THEORETICAL ANALYSIS

The block diagram of the first new voltage reference is presented in Figure 1.

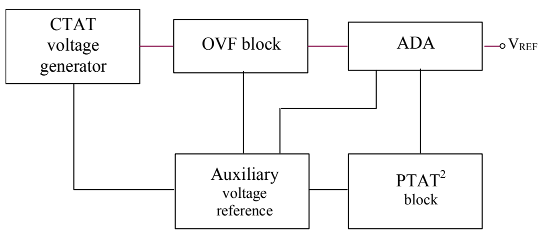


**Figure 1 - The block diagram of the voltage references**

The $CTAT$ voltage generator is implementing using the gate-source voltage of a MOS transistor working in weak inversion; its linear negative temperature dependence is compensated by the $OVF$ block [1], while its logarithmic dependent on temperature term is cancel out using a superior-order curvature-correction block $ADA$. The implementation of the previous technique is shown in Figure 2.

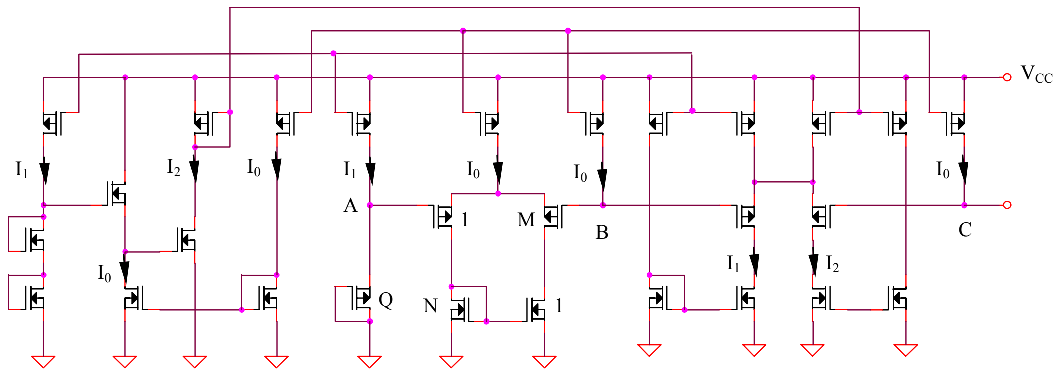


**Figure 2 - The CMOS logarithmic curvature-corrected voltage reference**

The reducing of the temperature coefficient for the second voltage reference (Figure 3) was made compensating the nonlinear temperature dependence of the gate-source voltage of a MOS transistor working in weak inversion with the difference between two gate-source voltages for MOS transistors with different temperature dependencies of theirs drain currents ( $PTAT$ and $PTAT^2$, respectively).

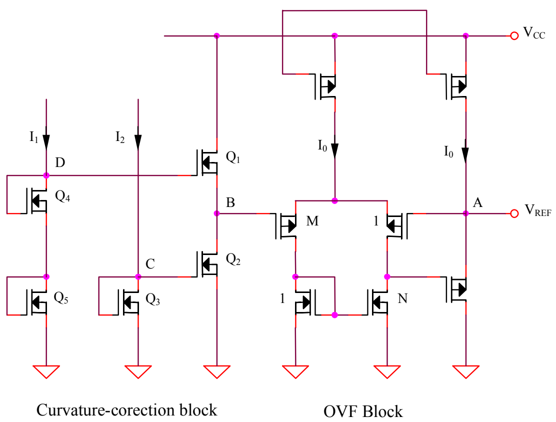


**Figure 3 - The second curvature-corrected voltage reference**

## 3. CONCLUSIONS

Two CMOS voltage references with superior-order curvature-corrections were presented. Original techniques for improving the circuits' temperature behavior use an $ADA$ block and the compensating of the nonlinear temperature dependence of the gate-source voltage by the difference between two other gate-source voltages. The circuits consume very small currents and are designed for a low-voltage operation ($V_{CC} = 2.5V$). The SPICE simulations confirm the theoretical estimated results ($TCR_1 = 36\,ppm/K$ and $TCR_2 = 2\,ppm/K$).

## 4. REFERENCES

1. Annema, A.J. (1997), "Low-Power Bandgap References Featuring DTMOSTs", *Philips Research Laboratories, The Netherlands*.