A Linear Transconductance Amplifier with Differential-Mode Bandwidth Extension and Common-Mode Compensation

Derui Kong, Sang Min Lee, Shahin Mehdizad Taleie, Michael Joseph McGowan, and Dongwon Seo

QUALCOMM TECHNOLOGIES, INC., SAN DIEGO, CA, USA

Motivation

1 Gm amplifier is widely used for voltage to current conversion[1]-[4].

2 Negative Gm amplifier has been used to boost DAC output impedance[5]. However, its bandwidth limits the impedance boosting at higher frequency.

3 The common mode loop bandwidth of Gm amplifier is much larger than differential loop, thus the common mode stability is often a problem. It is necessary to compensate common mode stability without decreasing differential loop bandwidth.

3 Negative cap can reduce parasitic cap and increase bandwidth of Gm amplifier, but it degrades common-mode stability further.

4 A technique to stabilize common mode loop while extending or maintaining differential loop bandwidth is needed.

PROPOSED GM AMPLIFIER

The proposed gm amplifier in Fig.1 has a gain of $1/R'$.

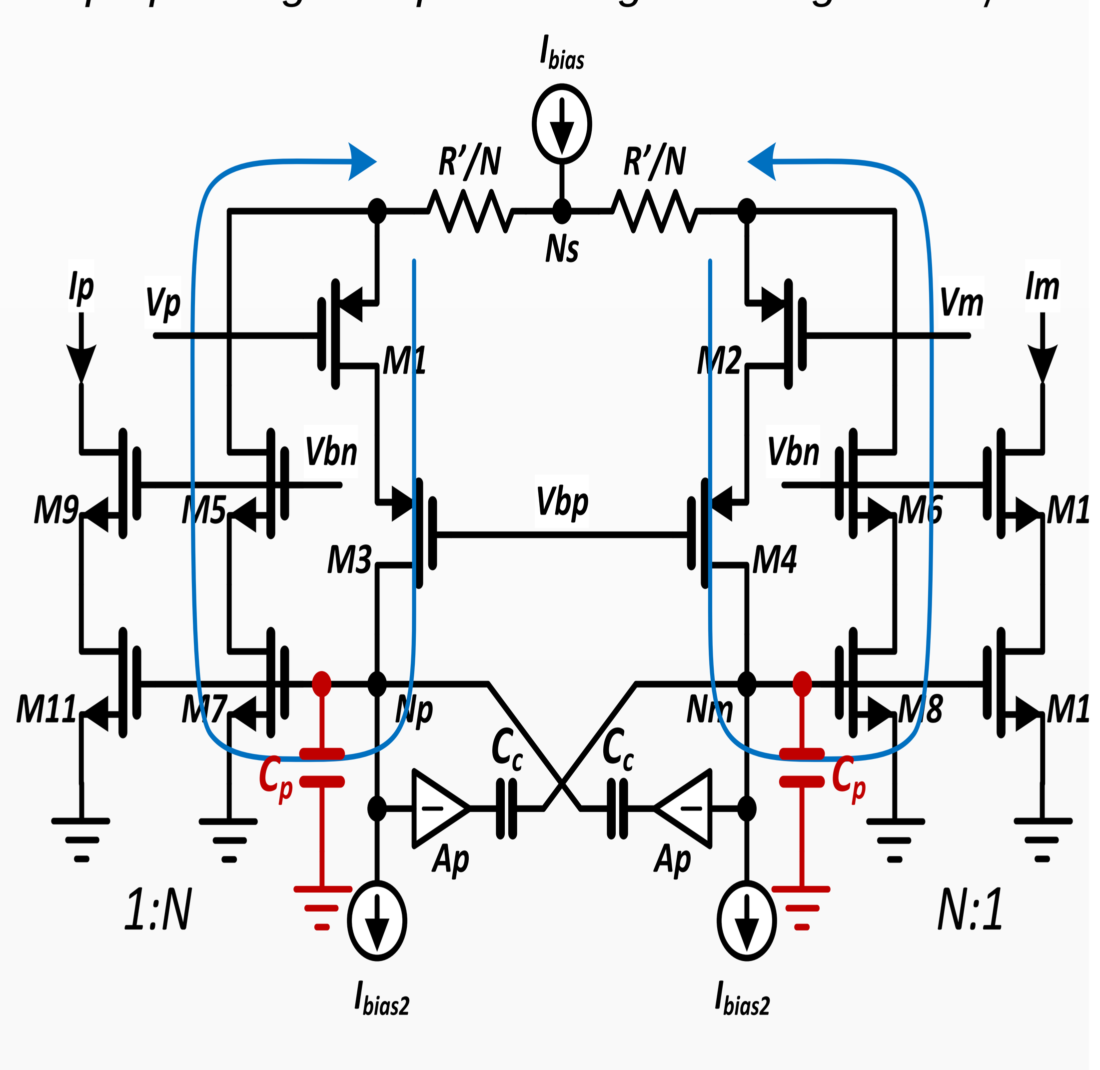

Figure 1. proposed transconductance amplifier.

Bandwidth of differential and common mode loop marked in blue *is :* $GBW_{DM} = \frac{g_{m7} g_{m1}(R'/N)}{(1+g_{m1}(R'/N))C_p}$ $\quad GBW_{CM} = \frac{g_{m7}}{C_p}$

Where $g_{m1}(R'/N) \ll 1$.

Differential bandwidth is low due to large parasitic C_p *and needs extension, common mode bandwidth is much higher and needs stabilization.* C_p *is dominated by routing cap and difficult to reduce.*

Proposed bandwidth tuning circuit consists of negative tunable gain buffers Ap and cross coupled capacitors C_c.

$$C_{L(DM)} = C_P + (1-|K|)\cdot C_c$$

$$C_{L(CM)} = C_P + (1+|K|)\cdot C_c$$

Advantages:

1 When $K < -1$, $C_{L(DM)} < C_P$ $\quad C_{L(CM)} > C_P$ *it introduces positive common mode capacitance for stabilization and negative differential capacitance for bandwidth extension, at no expense of additional noise and input offset.*

2 When $K = -1$, $C_{L(DM)} = C_P$ $\quad C_{L(CM)} > C_P$

It provides an alternative option of common mode compensation without impacting differential loop.

The complete circuit of gm amplifier with DM/CM bandwidth tuning is shown in Fig.2 MN is well biased by M7/M8, it is also sized the same as ML, thus $K = -g_{mMN}/g_{mML} = -\sqrt{M}$.

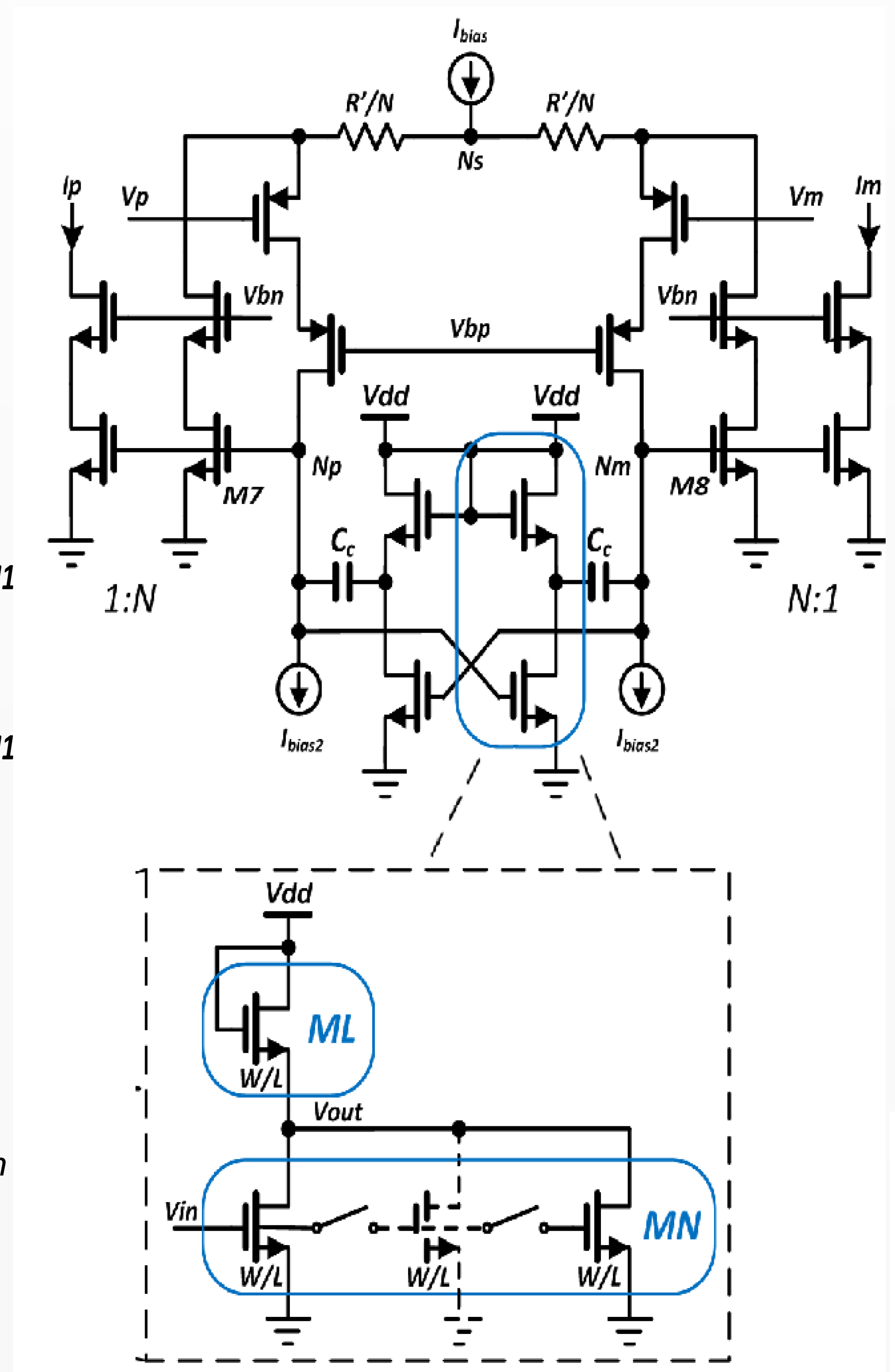

Figure 2. Complete circuit of transconductance amplifier.

SIMULATION RESULTS

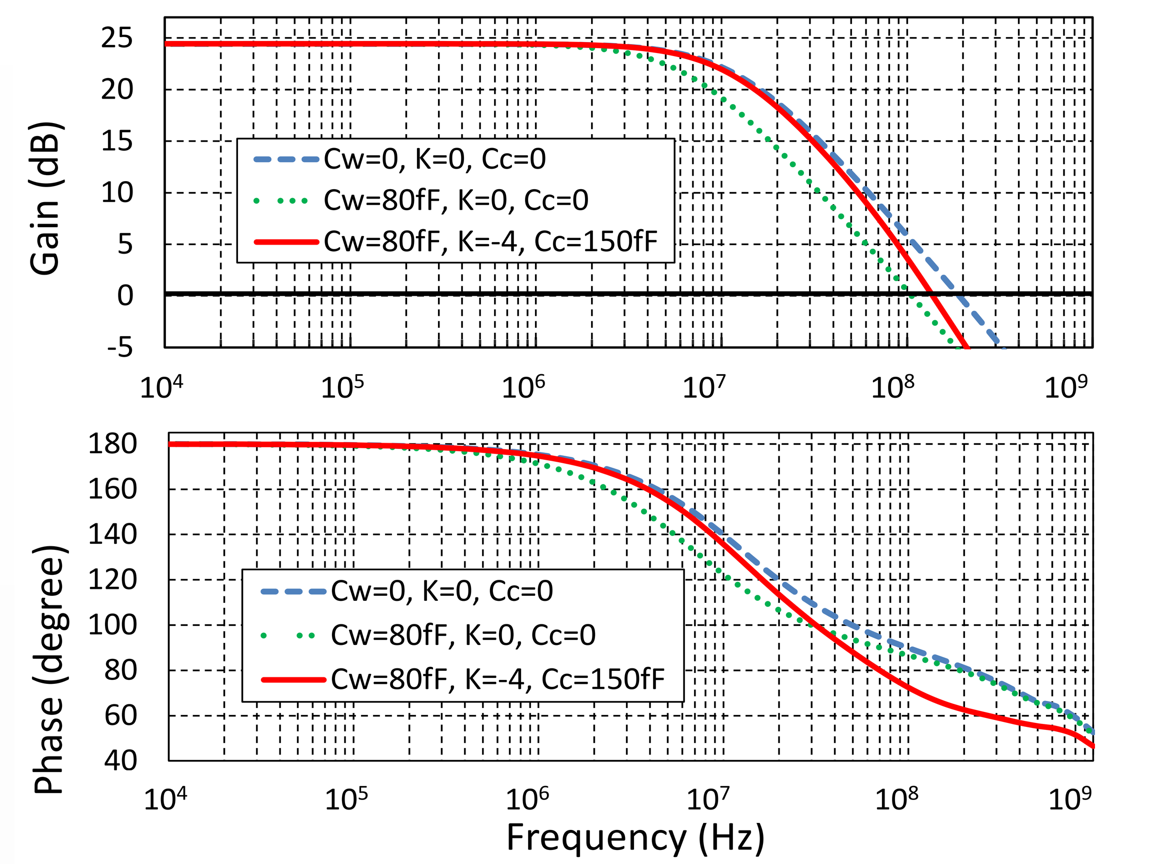

Figure 3.Diff mode mag/phase response w/wo extension.

Dashed curve: without routing cap, negative gain buffer off. (GBW/Phase Margin=200M/81.1°).

Dotted curve: 80fF routing cap added to C_p*,negative gain buffer off (100M/86.6°).*

Solid curve: 80fF routing cap, negative gain buffer on $K = -4$ *(140M/67.1°).*

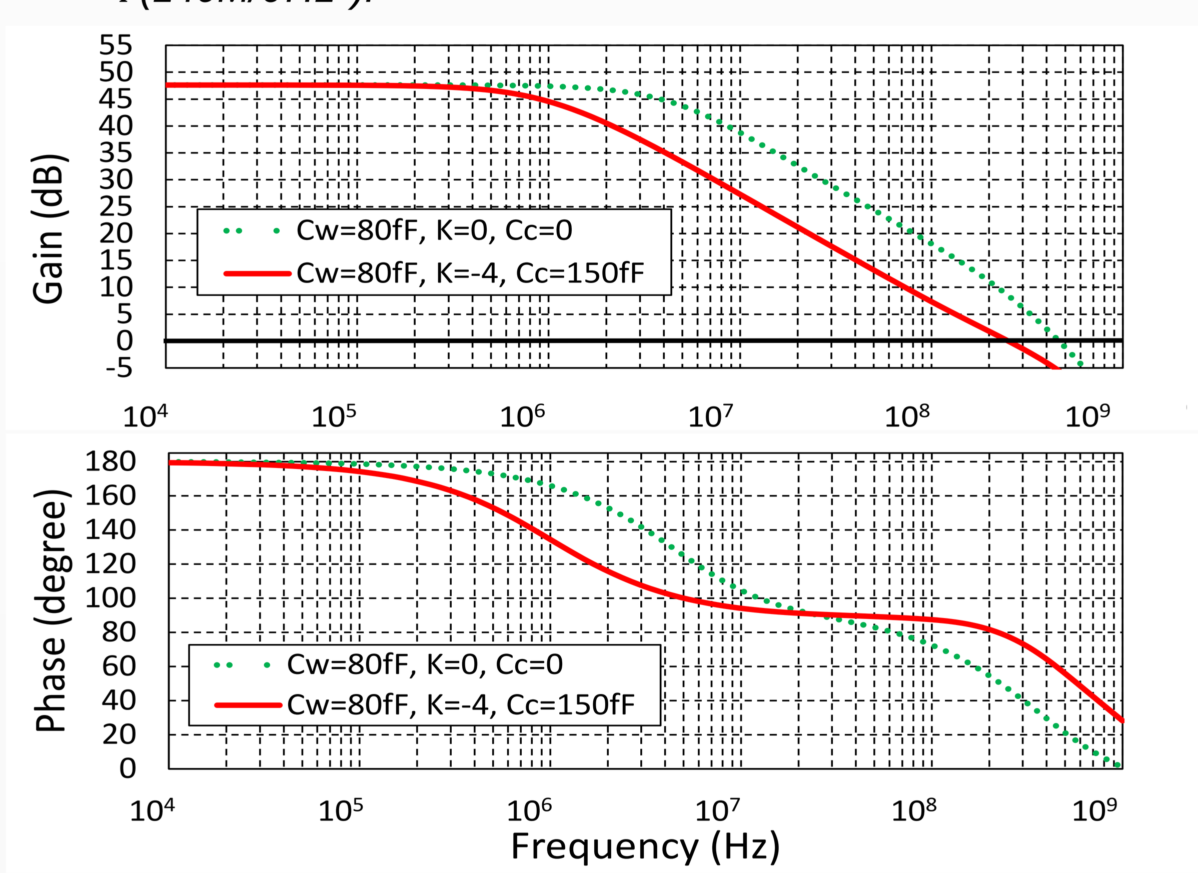

Figure 4.Cm mode mag/phase response w/wo stabilization.

Dotted curve: 80fF routing cap , negative gain buffer off (PM=23.9°).

Solid curve: 80fF routing cap, negative gain buffer on ($K = -4$*.(77.6°).*

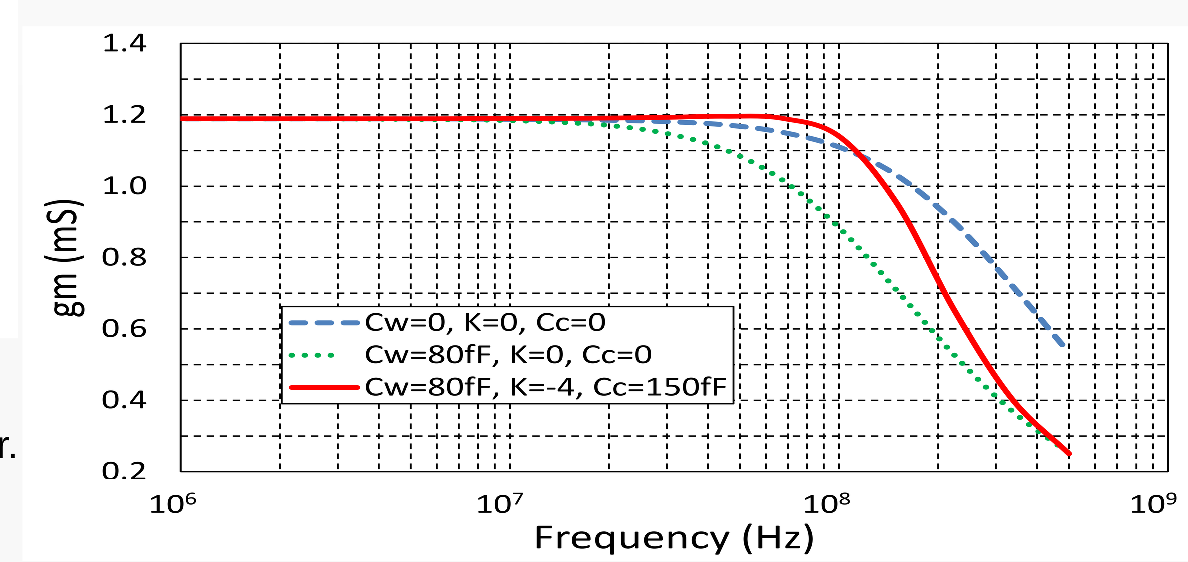

Figure 5. Freq response of transconductance amplifier w/wo extension.

Dashed curve: without routing cap, negative gain buffer off.

Dotted curve: 80fF routing cap, negative gain buffer off.

Solid curve: 80fF routing cap, negative gain buffers on $K = -4$.

APPLICATION IN DAC

Recently, a 14 bit R-2R current steering DAC with low distortion and noise for 4G standard is implemented [5]. The propose technique is used in a negative gm amplifier to cancel R2R output impedance and boost DAC output impedance(Fig. 6), thus improving SFDR at higher input frequencies.

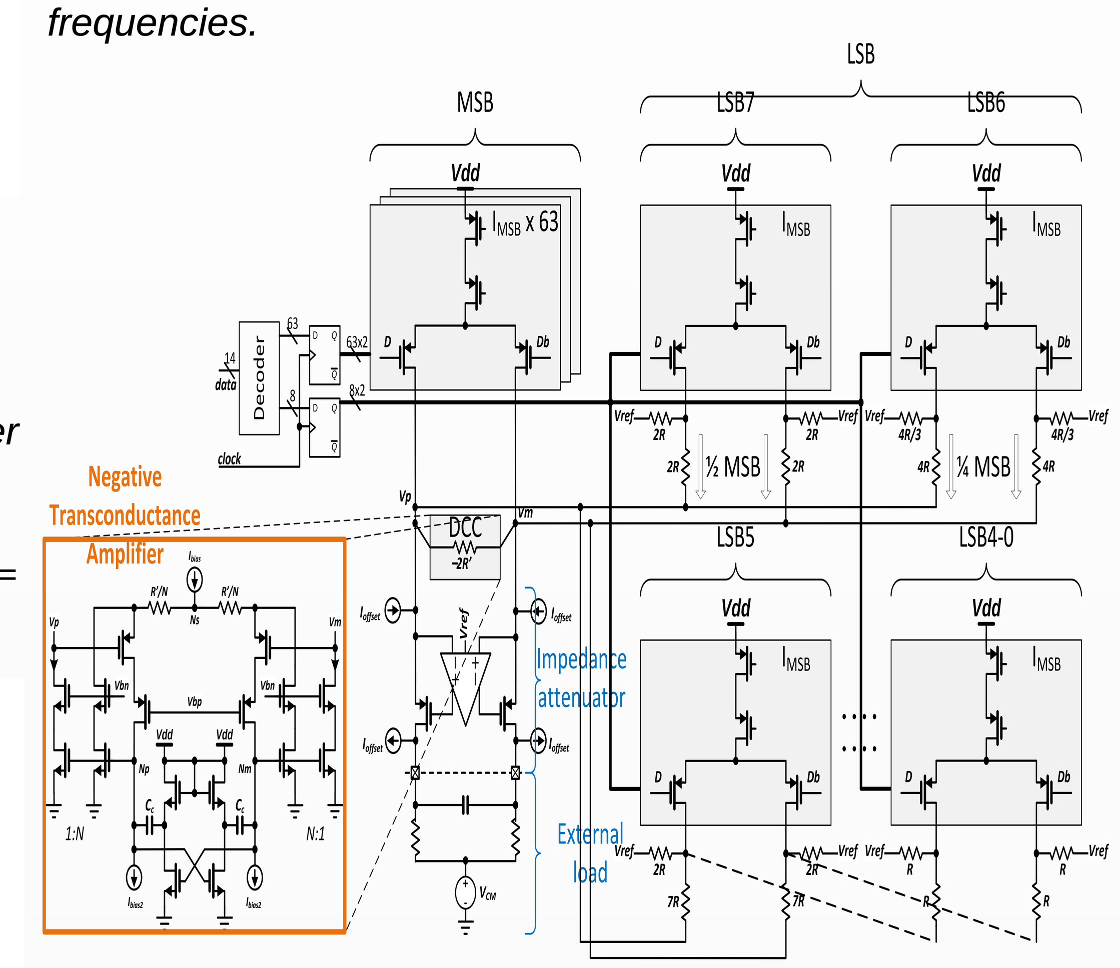

Figure 6. DAC with negative gm amplifier

EXPERIMENT RESULTS

20nm DAC runs at 270Msps with -1dB input tone swept across 5, 7.5, 9 and 12.5MHz. Fig. 7 shows the benefit of bandwidth tuning circuit as it improves HD3 with increasing negative buffer gain $|K|$*, with an improvement of 1.7dB for higher input frequency and* $K = -4$.

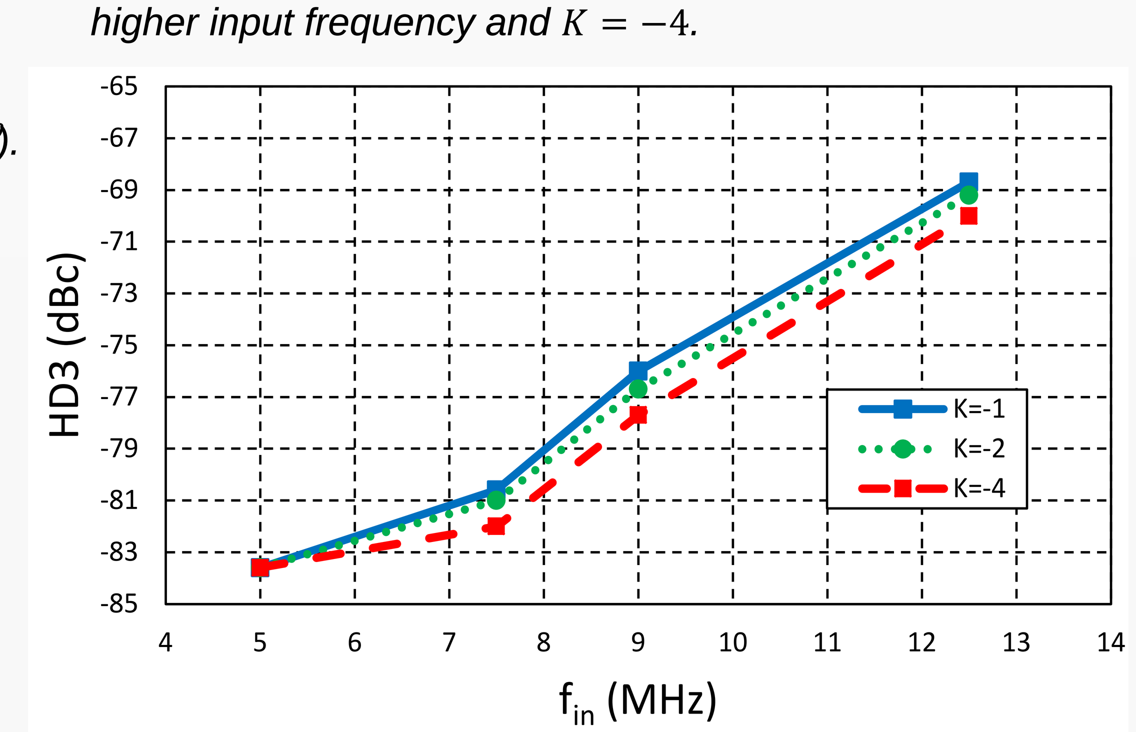

Figure 7. Measured HD3 with different K values.

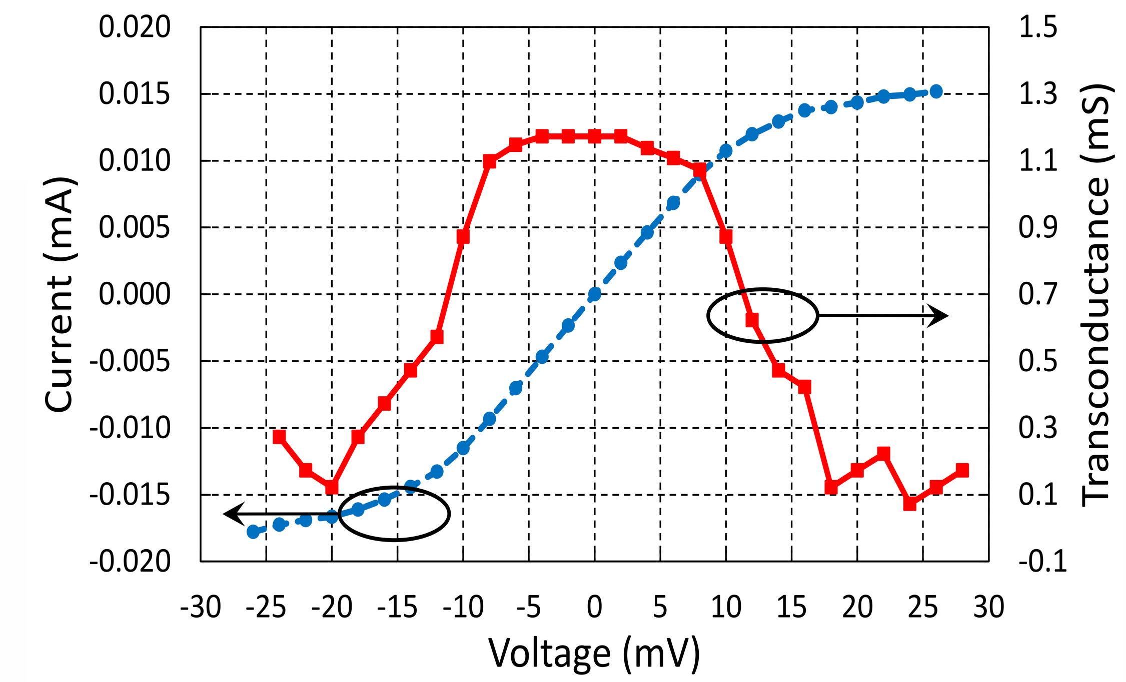

Figure 8. I-V curve and gm of transconductance amplifier.

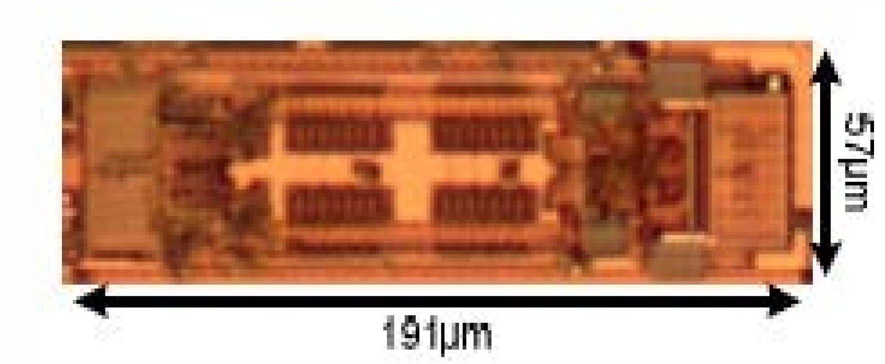

Figure 9. Die microphotograph of gm amplifier.

CONCLUSION

A differential mode bandwidth extension and common mode compensation technique using tunable negative gain buffers is proposed. The extended bandwidth contributes to better distortion in a DAC. This technique is also applicable to a wide range of circuits with a transconductance.

REFERENCE

[1]T. Kwan and K. Martin, “An adaptive analog continuous-time CMOS biquadratic filter,” IEEE J. Solid-State Circuits,1991.

[2]S. D. Willingham, K. W. Martin, and A. Ganesan, “A BiCMOS low-distortion 8-MHz low-pass filter,” IEEE J. Solid-State Circuits,1993.

[3]T. Arai, M. Koyama, H. Tanimoto, and Y. Yoshida, “A 2.5 V active lowpass filter using all-npn gain cells with a 1 Vpp linear input range,” ISSCC Dig.Tech. Papers,1993.

[4]A. Leuciuc, “A wide linear range low-voltage transconductor,” in Proc. IEEE ISCAS, 2003.

[5]S. M. Lee, D. Seo, S. M. Taleie, D. Kong, M. J. McGowan, T. Song, G. Saripalli, J. Kuo, and S. Bazarjani, “A 14b 750MS/s DAC in 20nm CMOS with <-168dBm/Hz noise floor beyond Nyquist and 79dBc SFDR utilizing a low glitch-noise hybrid R-2R architecture,” Dig. Symp. VLSI Circuits, 2015, to be published.