Class-AB Single-Stage OpAmp for Low-Power Switched-Capacitor Circuits

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Abstract

A new family of Class-AB OpAmp circuits based on single-stage topologies with non-linear current amplifiers is presented. The proposed architecture is characterized by generating all Class-AB current in the output transistors only. It exhibits low sensitivity to technology parameter variations and avoids the need for internal frequency compensation. It is suitable for low-power switched-capacitor circuits and optimized for a fast on-off operation and multi-decade load-capacitance specifications. A complete OpAmp design example is integrated in a standard 0.18-µm CMOS technology. Compared to the MOS-only state-of-the-art Class-AB OpAmps, the presented architecture obtains the highest figure of merit.

Type-II Circuit

Here, the crossing transistor (C) of the Type-I circuit is replaced by two split counterparts (C-C), which are auto-biased. Thus, extra reference circuits are not needed and power consumption is reduced.

Experimental Results

Operating at a 1.8-V power supply, a remarkable differential full scale of 1.3 Vpp is measured. The performance of the proposed OpAmp is compared with others from published Class-AB amplifiers [1]-[5] by using the figure of merit (FOM) from [5].

Practical Design

Type-II architecture is chosen for the design example in a 0.18-µm CMOS technology node. The OpAmp is stable for a wide range of load capacitance values. The OpAmp is integrated using a standard 0.18-µm CMOS technology, achieving an overall area of 0.07 mm². The circuits do not need any internal frequency compensation. The Class-AB current peaks are produced in the output transistors only. The resulting OpAmps exhibit low sensitivity to the technology parameter variations. Good performance is achieved using a simple design flow. The Type II has been successfully used in a 16-bit 100-kS/s 12-bit ADC.

Conclusions

- A new family of Class-AB OpAmps has been presented.
- The architecture is based on a single-stage topology.
- The circuits do not need any internal frequency compensation.
- The Class-AB current peaks are produced in the output transistors only.
- The resulting OpAmps exhibit low sensitivity to the technology parameter variations.
- Good performance is achieved using a simple design flow.
- The Type II has been successfully used in a 16-bit 100-kS/s 12-bit ADC.

References


Architecture

A single-stage OpAmp architecture is proposed with two complementary Class-AB control paths for the NMOS and PMOS output transistors.

Type-I Circuit

A cross-coupled pair (B-B) is introduced to provide the positive feedback for the Class-AB operation, while a crossing transistor (C) play the role of a feedback limiter.

Supposing strong inversion operation for all based devices, each non-linear current amplifier behaves as

\[ I_{onp} = 0 \quad V_{onp} = V_{Qu} \quad I_{opn} = I_{onp} = \frac{V_{Qu}}{2} \quad D = \frac{A}{A + B} \]  

From the Class-AB viewpoint, the wanted functionality for these voltage-controlled current mirrors is

- \[ I_{onp} = 0 \quad V_{onp} = V_{Qu} \quad I_{opn} = I_{onp} = \frac{V_{Qu}}{2} \quad \text{Bias point} \]
- \[ I_{onp} \neq 0 \quad V_{onp} \neq V_{Qu} \quad I_{opn} \neq I_{onp} \quad \text{Class-AB operation} \]

The process parameters \( \beta \) and \( \kappa \) disappear from the current-amplifier equation. Hence, independence from technology is achieved. Under Class-AB high modulation, common-mode currents can be injected to prevent a possible self-latch.

The circuit layout includes additional common-mode feedback (CMFB) averaging capacitors for switched-capacitor applications.

Experimental Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ideal</th>
<th>Simulated</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>4.5 V</td>
<td>4.5 V</td>
<td>4.5 V</td>
</tr>
<tr>
<td>DC gain</td>
<td>80.3</td>
<td>80</td>
<td>77.2</td>
</tr>
<tr>
<td>DC power</td>
<td>10 mW</td>
<td>10 mW</td>
<td>10 mW</td>
</tr>
<tr>
<td>Area</td>
<td>0.024 mm²</td>
<td>0.024 mm²</td>
<td>0.024 mm²</td>
</tr>
<tr>
<td>FOM</td>
<td>59.33</td>
<td>59.33</td>
<td>59.33</td>
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</tbody>
</table>

The works [1, 2] report higher FOM, but at the cost of requiring integrated resistors, which makes them more sensitive to technology parameter variations, and of a considerable lowering of their DC gain, which may be incompatible with high-precision applications. The works using MOS-only devices [3]–[5] present lower FOM and DC gain. Therefore, a contribution to the improvement of MOS-only Class-AB OpAmps is demonstrated.