Audio Pre-Amplifiers for Digital Electret Microphones in 0.18um CMOS Process

Aleksander Dec, Hiroshi Akima, Russell Mohn, and Ken Suyama

Epoch Microelectronics Inc., Tarrytown, NY
Motivation

- Objective: To design an audio pre-amplifier for an electret microphone in a CMOS technology

- Challenges:
  - Extremely high input impedance required
  - Stable self-bias of amplifier input to ground needed
  - Low noise required (must overcome 1/f noise of MOS devices)
  - On-chip high-pass filtering with corner frequency \(~20\text{Hz}\) desired.
The Conventional Solution

- JFET input self-biases to ground
- JFET input provides high input impedance (microphone capacitance and the input impedance form a high pass filter)
- JFET has low 1/f noise (junction device)

Challenge: JFET not available in the standard CMOS. Must achieve the same performance with MOS devices

The Current & Future Trends

Input: sound pressure / Output: 1-bit sigma-delta modulated digital data
Scope of This Work

CMOS audio preamplifier with voltage reference for sigma-delta modulator
Design Approach: Input

- Microphone & input form a highpass filter ($C_{MIC} \approx 10pF$)
  
  \[
  \frac{1}{2\pi \cdot R_{IN} \cdot C_{MIC}} < 20 \text{ Hz}
  \]

- Use back-to-back diodes to achieve an input impedance in the giga-ohm range (>796MΩ needed)

- Cascade resistor and back-to-back diodes to achieve 2kV HBM ESD protection for a 2V PMOS input transistor
Design Approach: Noise

(A) Use PMOS transistors as inputs for amplifiers and input level shifters (lower 1/f noise compared to NMOS devices).

(B) Use resistor degeneration for both NMOS & PMOS current sources to minimize the gain of the noise transfer function for 1/f noise.
Design Approach: High-Pass Filter

(A) Use a passive high-pass RC filter using long-channel MOS transistors in triode and linearize by keeping $V_{GS}$ constant

(B) Realize high-pass response using DC-servo loop
Replica-Bias Pre-Amplifier (AMP1)

No on-chip high-pass filter function

$M_{P1} - M_{P4}$ designed equal-size to set the bias voltages to 1V
Pre-Amplifier + HPF (AMP2)

On-chip passive high-pass filter using long-channel PMOS transistor $M_{P4}$ in triode (constant $V_{GS}$)
Pre-Amplifier + DC-Servo (AMP3)

On-chip high-pass filter using DC-servo loop
Opamp with Class-AB Output

Class-AB output stage chosen to drive resistive load
Improved PSRR compensation approach used

 Improved PSRR compensation approach used in both bandgap and regulating amplifier
Constant-Gm bias circuit used to reduce opamp unity gain bandwidth variation over temperature & supply
Chip Layout (AMP1)

Active Area = 730um x 530um (0.18um CMOS)
 Voltage Gain (AMP1)

Voltage Gain = 556mV_{PPS}/100mV_{PPS} (14.9dB)
Frequency Response (AMP1)

Bandwidth (3dB) = 329kHz
Harmonic Distortion (AMP1)

THD ($V_{OUT}=1V_{PPS}$, 1kHz) = -65dBc
Chip Layout (AMP2)

Active Area = 730um x 560um (0.18um CMOS)
Voltage Gain (AMP2)

Voltage Gain = \(552 \text{mV}_{\text{PPS}} / 100 \text{mV}_{\text{PPS}}\) (14.8dB)

Input @ 2kHz
Frequency Response (AMP2)

Bandwidth (3dB) = 322kHz
Harmonic Distortion (AMP2)

THD \((V_{\text{OUT}}=1V_{\text{PPS}}, 1\text{kHz})\) = -60dBc
Chip Layout (AMP3)

Active Area = 800um x 660um (0.18um CMOS)
Voltage Gain (AMP3)

Voltage Gain = 264mV_{PPS}/50mV_{PPS} (14.5dB)
Bandwidth (3dB) = 372kHz
Harmonic Distortion (AMP3)

THD ($V_{OUT}=1V_{PPS}$, 1kHz) = -64dBc
# Summary

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<th>AMP1</th>
<th>AMP2</th>
<th>AMP3</th>
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Conclusion

• Three amplifier architectures for electret microphone were presented.

• AMP1 was found to be susceptible to low-frequency disturbance, and demonstrated the need for additional on-chip high-pass filtering.

• On balance, AMP2 was found to be the most suitable amplifier architecture for electret microphone.
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