Analog IC Design : Course Project

Monsoon 2021, IIIT Hyderabad (Instructor: Abhishek Srivastava)

Due date : 4 Dec, 2021 (18:00 hrs)

Instructions:

1. Submit your project report in form of pdf (Name_RollNo.pdf) at moodle on or before the due date
2. Use the given TSMC 180 nm technology file for the simulations.
3. Design the circuit for $V_{DD} \leq 1.8$ V.

1 Design specifications

Design a differential input, single ended output operational transconductance amplifier (OTA) with the lowest possible power consumption for the following specifications :

- DC gain $\geq$ 80dB.
- Unity gain frequency $\geq$ 10 MHz.
- Output voltage swing $\geq 1V_{pp}$.
- Slew rate $\geq$ 100V/μs.
- Phase Margin $\geq 65^{\circ}$.
- Input referred noise (Thermal only) = 10nv/$\sqrt{Hz}$.
- Input Common mode voltage = 0.9V.
- Output load capacitance = 1pF .

2 Architecture and hand calculations

(a) Choose the appropriate architecture with reasoning [5 + 15 (bonus)]
Bonus marks will be awarded for architecture other than the classical two stage OTA. For example : You can try to implement the OTA as reported in "Operational Transconductance Amplifier With Class-B Slew-Rate Boosting for Fast High-Performance Switched Capacitor Circuits", Naderi, et. al., TCAS-I, 2018.

(b) Clearly draw the schematic using xcircuit or some other drawing software and label the transistors, resistors and capacitors [5]

(c) Show the step-by-step design procedure and calculations [10]

(d) Tabulate the design parameters (W, L, R, C, I) [5]

(e) Tabulate the calculated specifications (gain, unity gain bandwidth, slew rate, phase margin, slew rate) [5]

3 Simulations

(a) Write the netlist with comments to clearly explain the circuit. [10]

(b) Tabulate the design parameters (W, L, R, C, I etc) and compare with the hand calculate values [5]

(c) OPERATING POINT [5]
Perform the dc operating point analysis with the OTA in unity gain feedback mode. Clearly annotate and report the dc operating point voltages at every node on the schematic.

(d) STB ANALYSIS: [5]
report the DC gain, unity gain frequency and the phase margin. Also show the magnitude and phase plot.

(e) SLEW RATE: [5]
With the OTA in unity gain feedback mode, apply a positive step from 0 to 1.8V with a rise time of 100ps. Measure the slew rate and clearly show the output plot in the slewing region with cursors.

(f) SETTLING TIME: [5]
With the OTA in unity gain feedback mode, apply the same step input as above. Measure and report the settling time, t_s for 2% accuracy.

(g) SYSTEMATIC OFFSET: [5]
With the OTA in unity gain feedback mode, measure and report the systematic offset value using dc analysis. Clearly show the output node voltage on the schematic.

(h) NOISE: [5]
Show the input referred noise PSD from 1Hz to 1GHz band. Clearly show the RMS thermal noise voltage in the plot (with cursor). Report the integrated noise voltage over the unity gain bandwidth.

(i) CMRR: [5]
Plot the open loop CM gain of the OTA with clear labels. Report the CMRR of the OTA.

(j) PSRR: [5]
Perform the PSRR simulation by adding a small signal component only on the voltage supply of the OTA. Plot and report the PSRR value with clear labels (Open loop).

(k) INPUT COMMON MODE RANGE: Sweep the input common mode voltage in the unity gain configuration and report the maximum input common mode range of the OTA. [5]

(l) CLOSED LOOP GAIN: With the OTA in unity gain feedback mode, perform ac analysis and report the DC gain and the -3dB frequency. [5]

(m) CLOSED LOOP TRANSIENT ANALYSIS: [5]
With the OTA in unity gain feedback mode, apply a sinusoidal signal of 10KHz frequency for maximum signal swing at the output without distortion.

(n) POWER CONSUMPTION: [5]
Report the total current and power consumption of the OTA.

4 Layout [30]
Layout your circuit using MAGIC and the previously given technology file. Perform post-layout simulations mentioned in part-3.

5 Tabulating the results [10]
From the schematic and post-layout simulations, tabulate the Opamp performance (DC gain, unity gain frequency, phase margin, ICMR, CMRR, PSRR, slew rate, output swing (peak to peak), RMS thermal noise, power) and compare with the required specifications. (Table columns - specifications — Schematic — Post-layout)

6 Design example
Use the above OTA and design the following :

(a) Multiply-by-two circuit : $v_{out} = 2 \times v_{in}$ [10]
Refer to section 13.3.3 of Razavi, second edition. For the design, MOS switches must be used. Clearly tabulate the components values and switch sizes. Show the transient analysis results for $v_{out} = 2 \times v_{in}$. [10]

(b) Implement a transimpedance amplifier (TIA) which can take current input and can convert it into voltage providing transimpedance gain of 500 kΩ. Clearly tabulate the components values. Show the transient analysis results.

7 Project report [20]
Project report must be concise and systematic. Professional write up is expected. The best report will be awarded bonus (10) marks. The best executed project will be given a prize and will be announced on the moodle.

8 Project viva [20]
It will be held on 3^{rd} and 4^{th} Dec, 2021. Timings will be intimated later.