Chapter 7

Conclusions and Future Scope of Work

7.1 Conclusions

- A new methodology based on the concept of figure of merit that includes the three performance parameters, namely input-referred noise, differential dc gain and unity-gain bandwidth, has been proposed for synthesizing optimal performance differential amplifiers under the constraints of area. The figure of merit peaks at a certain value of relative area allocation to the input transistors in the range of $\mathbf{60}$ % to $\mathbf{80}$ % of the available area. The peak value of figure of merit is a function of area. However, it is independent of biasing current (and therefore power consumption) subject to the minimum current (and therefore a minimum power) required to keep all the transistors biased in the saturation region. The peak figure of merit and minimum power required to achieve the peak figure of merit are thus both functions of area. These analyses help in synthesizing optimal differential amplifier circuit designs under area constraints.
- The above concept has been validated with examples of input stage differential amplifier and second stage amplifier designs both at low and medium/moderate frequencies. It is observed that the dc gain, bandwidth and noise achieved at peak $\boldsymbol{FoM}$ are very close to the best achievable values.
- The above ideas have been incorporated in a CAD Tool developed in C/C++, for the synthesis of differential amplifiers. The tool has been tested for 2400 design-syntheses with dc power varying from 100 to 1000 mW, dc voltage gain in the range of 10 – 1000, unity-gain bandwidth in the range of 1– 100 MHz, and input-referred noise in the range of 1 – 20 $\boldsymbol{nV/rtHz}$.

- The synthesized circuits are mainly governed by power and noise. Area required increases exponentially with reduced noise requirement. Area requirement can be reduced with increased power for the same input-referred noise. Hence, a clear Area – Power tradeoff is seen in the synthesized designs.
- The proposed concept of figure of merit is a suitable approach for synthesizing optimal designs of differential input stage of two-stage compensated operational amplifiers under area constraints and leads to the realization of differential dc gain, unity-gain bandwidth and input-referred noise values that are also very close to their individually achievable best values under the same area constraints.
- The analyses validate that the idea of FoM may be employed in a CAD tool for automatically synthesizing differential input stage amplifiers and can be extended for other building blocks. The study also highlights that the total band noise for a given area is almost constant and also does not vary significantly with total area assigned to the circuit.
- The limits and limiting relationships on differential dc voltage gain Ad, and unity-gain bandwidth UGB, of an unloaded differential amplifier were explored. It has been observed that the product $Ad \cdot UGB$ of an unloaded differential amplifier is a technology constant.
- The layouts of some of the synthesized circuits were drawn manually and were simulated and compared against simulated results on schematics. The results are in close match agreement.

7.2 Future Scope of Work

- The concept of Figure of Merit based synthesis can be extended for more analog circuit blocks.
- Studies can be extended to the relative area allocations between various stages of an amplifier.

- More performance parameters, like Input common mode range, slew rate, *etc*. may be included in Figure of Merit, and bounding limits as well as the feasibility of realization of a given set of performance parameters vis-à-vis a given technology analyzed to guide the user to not set goals unrealizable through a given technology.
- Formulation of these limits and their simultaneous realizability can also be used to select an appropriate technology (if one exists) and the associated area and power requirement for the realization of all the performance parameters.