**Design of a Flipped Voltage Follower Based Low Dropout Voltage Regulator**

**Internship Report**

***submitted in Partial Fulfillment for the Award of***

**Master of Technology**

**by**

**Nalamothu Sai Sampath**

**(MT2023525)**

***to***



**INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY BANGALORE**

**JUNE 2025**

**CERTIFICATE**

This is to certify that the internship report titled, **‘Design of a Flipped Voltage Follower Based Low Dropout Voltage Regulator’** submitted by **‘Nalamothu Sai Sampath’ (MT2023525)** is a bona fide work carried out under my/our supervision at ‘Samsung Semiconductor India Research (SSIR)’ from 29-07-2024 to 29-06-2025 (11 Months), in partial fulfilment of the Master of Technology course of International Institute of Information Technology Bangalore.

His performance during the internship was satisfactory,

(Signature of the Supervisor)

Supervisor Name

Address of the Company

(with seal)

Date:

Place:Bengaluru

**Undertaking by the Student**

I, **Nalamothu Sai Sampath**, hereby declare that the report of the internship program titled, “**Design of a Flipped Voltage Follower Based Low Dropout Voltage Regulator**” is prepared by me. I also confirm that, the report is only prepared for my academic requirement and not for any other purposes.

I also confirm that, the submitted softcopy has been reviewed and approved for submission by my supervisor.

Signature of the Student

(Roll Number)

Date:

Place: Bengaluru

**ACKNOWLEDGEMENT**

I would like to thank everyone who helped and supported me during my internship. This experience has been a great learning journey, and I am truly grateful to all those who made it possible.

First, I would like to thank my mentors and managers at **SSIR**. They guided me throughout the internship, helped me understand new concepts, and always encouraged me to do my best. I learned a lot from their experience, and their support made a big difference in my work.

I also want to thank my professors at **IIIT Bangalore**. Their teaching gave me the strong foundation I needed to take on this internship. The knowledge and skills I gained in their classes helped me face the tasks and challenges with confidence.

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**ABSTRACT**

As part of my internship at **Samsung Semiconductor India Research (SSIR)**, I gained hands-on experience in Analog circuit design, working on both foundational concepts and practical applications. I began by studying the **Flipped Voltage Follower (FVF)** topology and its behaviour, followed by an in-depth understanding of **low-voltage cascode current mirrors,** which are essential in low-power analog circuits. I also explored the architecture and operation of the **folded cascode operational transconductance amplifier (OTA).**

During the internship, I conducted **DC and AC analysis of an NMOS-based FVF**, which helped me understand its biasing, small-signal response, and frequency behaviour. Additionally, I was assigned an **OTA**, for which I performed **DC and AC analysis** to estimate important performance parameters such as gain, bandwidth, and output impedance.

Applying these learnings, I worked on the **Design of a Flipped Voltage Follower-based Low Dropout Regulator (LDO)**, focusing on achieving low dropout voltage, stable operation, and good performance under varying load conditions.

In addition to technical skills, my internship at SSIR helped me develop important **soft skills** such as time management, clear technical communication, teamwork, and effective documentation. I believe that both the technical knowledge and soft skills gained during this internship will be highly valuable in my future journey in the semiconductor industry, enabling me to contribute effectively to complex design challenges and collaborative projects.

**1. INTRODUCTION**

* 1. **About the Company**

**Samsung Semiconductor India Research (SSIR)** is a pivotal research and development center located in Bengaluru, Karnataka. As part of Samsung Electronics Co., Ltd., SSIR plays a significant role in advancing semiconductor technologies, contributing to Samsung's global innovation ecosystem.

* + 1. **Core Areas of Focus**

SSIR specializes in three primary domains:

* **Memory**: Developing industry-leading DRAM and Flash memory products tailored for applications such as servers, big data, AI/HPC, IoT, and 5G.
* **System LSI** : Providing tailored solutions encompassing high-performance processors, power management ICs (PMIC), and advanced image sensors that enhance device functionality.
* **Foundry**: Offering comprehensive foundry solutions that support performance computing and automotive applications through cutting-edge process technologies and advanced packaging techniques.
  + 1. **Commitment to Innovation and Community**

SSIR is dedicated to continuous innovation in semiconductor technologies, driving digital transformation across various industries. The centre also emphasizes corporate social responsibility, engaging in initiatives like the "Chip Design for High School" program in collaboration with IIIT-Bangalore, aiming to equip young minds with essential skills in semiconductor design.

* 1. **My role, responsibilities and contribution**

During my internship at Samsung Semiconductor India Research (SSIR), I was part of the IPD Analog Team which is a part of Foundry domain in SSIR. My role primarily focused on learning, analyzing, and contributing to the design of analog building blocks used in IP development for advanced semiconductor technologies.

One of my first tasks involved gaining a deep understanding of fundamental analog circuits, such as the Flipped Voltage Follower (FVF), low-voltage cascode current mirrors, and the folded cascode operational transconductance amplifier (OTA). I studied their operation in depth, with emphasis on how these blocks are used in low-voltage and low-power designs, which are essential in modern semiconductor processes.

I then applied this knowledge in a practical setting by performing DC and AC analysis of an NMOS-based Flipped Voltage Follower, where I examined its operating point, output impedance, frequency response, and overall performance. This helped me build a strong understanding of its behaviour under different biasing and load conditions. I was also given a black-box OTA to analyse, for which I carried out detailed DC and AC characterization to extract important design parameters such as gain, bandwidth, and output resistance. This exercise sharpened my skills in interpreting simulation data and understanding the internal functionality of complex analog blocks.

Building on these learnings, I was given the opportunity to design a Low-Dropout Regulator (LDO) using the Flipped Voltage Follower topology. In this task, I focused on achieving a stable output with a low dropout voltage, and I ensured the design met performance under varying load conditions. I used tools such as Cadence Virtuoso and standard analog design methodologies for transistor sizing, to implement and simulate the circuit. Throughout this process, I conducted regular simulations, documented results, and refined the design based on mentor feedback.

In addition to the technical aspects, the internship also helped me develop several important soft skills. I improved my ability to communicate technical results clearly during review meetings, manage tasks effectively to meet deadlines, and collaborate as part of a larger design team. These skills were essential in maintaining the professional pace and expectations of a fast-moving semiconductor design environment.

**2. INTERNSHIP DETAILS**

**2.1 Job Description**

Describe in detail the projects/ assignments you were involved in, including your role and contributions, details about the routine tasks and responsibilities assigned to you during the internship, if involved/ collaborated with other teams in completing the assigned tasks and also specify the objectives and the deliverables/ outcomes of the assigned tasks.

**2.2 Technologies/Methodologies used**

Provide details about the methodology and the tools and technologies used to accomplish the assigned task successfully.

**2.3 Challenges and the Solutions**

List out any challenges faced by you in completing the assigned tasks and the solutions used to overcome those problems/challenges with brief explanation.

**3. SKILLS DEVELOPED**

**3.1 Details of the Technical Skills (TS)**

**3.1.1. Understanding and Analysis of Analog Building Blocks**

I gained in-depth knowledge of essential analog circuit blocks used in IP development:

* Flipped Voltage Follower (FVF): I studied how the FVF functions as a buffer with very low output impedance and minimal voltage dropout. I explored its use in fast-response and low-voltage regulation circuits such as LDOs.
* Low-Voltage Cascode Current Mirrors: I understood how cascode current mirrors enhance current accuracy and output resistance, especially in low supply voltage environments typical in advanced process nodes.
* Folded Cascode OTA (Operational Transconductance Amplifier): I explored the structure of folded cascode OTAs, known for their high gain, large input common-mode range, and good output swing, and how they are used in precision analog applications.

**3.1.2. DC and AC Simulation and Analysis**

Using Cadence Virtuoso and Spectre, I performed a wide range of simulations to analyze circuit behavior:

* DC Analysis: I analysed operating points to verify biasing conditions, current distribution, and proper region of operation for each transistor in the design.
* AC Analysis: I studied gain, bandwidth, unity-gain frequency (UGF), and phase response. I learned to read and interpret Bode plots to understand frequency-domain behavior.
* Black-Box OTA Characterization: I was given an unknown OTA for which I performed DC and AC simulations to extract its performance parameters. This task strengthened my ability to analyse and interpret circuit behavior from outputs alone.

**3.1.3. Design and Implementation of FVF-Based LDO**

A major technical task during the internship involved designing a Low-Dropout Regulator (LDO) using the Flipped Voltage Follower topology:

* Architecture Selection and Design: I selected the FVF-based topology for its low dropout characteristics and fast transient response. I designed the LDO at the transistor level with attention to sizing, biasing, and load conditions.
* Stability Analysis: I performed open-loop gain and phase analysis to ensure that the LDO was stable across different operating conditions. I identified the dominant and non-dominant poles of the system and ensured sufficient phase margin to avoid oscillations or overshoot during transient behavior.
* Load and Corner Simulations: I tested the LDO under various load currents and across PVT (process, voltage, and temperature) corners to ensure consistent and robust performance.

**3.1.4. Debugging and Simulation Validation**

I developed strong problem-solving skills through hands-on debugging of design and simulation issues, including:

* Fixing biasing errors and convergence issues in simulations.
* Analysing waveform anomalies such as voltage overshoots, slow settling, or unexpected gain roll-off.
* Verifying circuit behavior under start up and dynamic load transitions.

I used a combination of operating point, AC, transient, and loop-gain analyses to validate my designs thoroughly.

**3.1.5. Tool Proficiency and Industry Practices**

Throughout the internship, I became proficient in key tools and practices used in analog design:

* Cadence Virtuoso for schematic capture.
* Spectre Simulator for precise analog simulation and verification.
* Waveform viewers (ADE Explorer) for analysing and documenting results.
* Maintaining structured design documentation and presenting results in regular reviews.

These technical experiences gave me a strong foundation in analog IC design, from both theoretical and practical perspectives. The ability to perform stability analysis, design analog blocks under real-world constraints, and work within a professional tool flow has prepared me well for a future in the semiconductor industry, especially in analog design domain.

**3.2 Details of the Soft Skills (SS)**

#### ****3.2.1. Analytical Thinking****

I developed the ability to debug circuits logically and validate designs using theoretical principles. This involved interpreting simulation results and correlating them with expected analog behavior. It sharpened my critical thinking while troubleshooting and improving circuit performance.

#### ****3.2.2. Communication Skills****

I learned to document complex technical observations in a clear and structured format.  
This skill was crucial when creating reports and sharing updates with mentors or team members. It also helped me explain circuit behaviours and seek feedback effectively.

#### ****3.2.3. Time Management****

Balancing literature study, schematic design, simulation, and documentation improved my time efficiency. I learned to prioritize tasks and meet deadlines during each project phase.  
This helped ensure steady progress without compromising quality.

#### ****3.2.4. Attention to Detail****

Working on analog circuits demanded a careful eye for subtle performance issues and variations. I analyzed biasing, gain, and frequency responses with precision to ensure robustness. Small changes often had large impacts, so I learned to be meticulous in design evaluation.

#### ****3.2.5. Team Collaboration****

I frequently discussed design ideas and simulation outcomes with mentors and colleagues.  
Their suggestions helped me refine my approach and better understand industry expectations.  
Collaborating in a supportive team environment enhanced both my confidence and learning.

**4. KEY LEARNING FROM THE INTERNSHIP**

My internship at Samsung Semiconductor India Research (SSIR) has been an enriching and transformative experience that has contributed immensely to my personal and professional development. On the professional front, I gained strong practical knowledge of analog integrated circuit design, which is critical for the semiconductor industry. I had the opportunity to work closely on important circuit blocks such as flipped voltage followers (FVF), low-voltage cascode current mirrors, and folded cascode operational transconductance amplifiers (OTAs). Through rigorous DC and AC analysis, stability evaluations, and detailed simulations, I developed a deeper understanding of circuit behavior under different operating conditions. Designing an FVF-based low dropout regulator (LDO) from scratch gave me hands-on experience in the entire design cycle, including architectural decisions, transistor-level implementation, and performance verification. Moreover, I became proficient with industry-standard design tools like Cadence Virtuoso and Spectre Simulator, which prepared me to work efficiently in a professional semiconductor environment.

Beyond technical skills, the internship greatly enhanced my soft skills and professional demeanour. I learned how to communicate complex technical concepts clearly, both verbally and in writing, which is essential for collaborating with mentors and team members. Managing multiple tasks simultaneously from literature review and simulation to analysis and reporting—helped me improve my time management and prioritization abilities. The dynamic nature of design work taught me to be adaptable, quickly learning new concepts and modifying my approach based on simulation results and feedback. Attention to detail became second nature as I realized that even small changes could significantly impact circuit performance, emphasizing the importance of precision in analog design. Furthermore, working as part of a team exposed me to collaborative problem-solving and constructive feedback, which enhanced my interpersonal skills and professional confidence.

Personally, this internship experience strengthened my self-discipline, work ethic, and motivation. It gave me a realistic perspective on the challenges and demands of the semiconductor industry and inspired me to continue learning and improving. Overall, the combination of technical expertise and soft skills I acquired during my time at SSIR has prepared me well for my future career, equipping me with the knowledge, skills, and mind-set needed to succeed in the fast-evolving field of semiconductor design.

**5. CONCLUSION**

In conclusion my internship at Samsung Semiconductor India Research (SSIR) has been a highly valuable and rewarding experience. It provided me with a solid foundation in analog circuit design through hands-on exposure to key building blocks, detailed simulations, and real-world design challenges. The technical knowledge and practical skills I acquired, combined with the development of essential soft skills, have significantly enhanced my overall competency and confidence. This internship has not only deepened my understanding of semiconductor design but also prepared me to contribute effectively in a professional engineering environment.

Additionally, the exposure to a collaborative work culture and the opportunity to engage with experienced professionals helped me appreciate the importance of teamwork, clear communication, and adaptability in a fast-paced industry. I learned to manage my time efficiently, balance multiple responsibilities, and approach problems with analytical thinking and creativity. These experiences have strengthened my problem-solving skills and taught me the value of attention to detail and perseverance.

I am truly grateful for the continuous guidance and support I received from my mentors, professors, and peers throughout this journey. Their constructive feedback and encouragement played a pivotal role in my growth. Overall, this internship has been a critical step in my career development, equipping me with both technical expertise and professional maturity.

I look forward to applying the lessons learned during this internship to my future academic pursuits and career in the semiconductor industry, confident that the skills and knowledge gained will enable me to make meaningful contributions and embrace new challenges with enthusiasm.

**GLOSSARY**

SS Soft Skills

TS Technical Skills

**(**List the abbreviations used in the report alphabetically**).**

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4. Author/ Title of Weblink. url, accessed: [Month, Date, Year] (for online only resource).