



Summer Fellowship Report

On

Spoken Tutorial Project - eSim

Submitted by

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Chapter 1

Introduction

1.1 Project Overview and Scope

This internship, under the FOSSEE (Free and Open-Source Software for Education) initiative at IIT Bombay, focused on expanding the training materials for **eSim**, a powerful open-source EDA (Electronic Design Automation) tool. The core objective was to create high-quality Spoken Tutorials demonstrating the use of eSim with modern, industrial-grade open-source Process Design Kits (PDKs)—specifically the **SKY130** and **IHP Open PDK**.

The work encompassed the entire content development lifecycle, involving **scriptwriting, audio recording, video production**, and developing foundational command-line materials to prepare the target simulation environments. The resulting tutorials serve to democratize access to advanced VLSI simulation techniques.

Chapter 2

Technical Contributions and Execution

2.1 Tutorial 1: eSim on Cloud and Analog Fundamentals

This foundational tutorial, for which the **script** and **audio recording** were completed, introduced the accessibility of the **eSim on Cloud** platform. This web-based environment lowers the barrier to entry for users by eliminating complex local setup. The tutorial focused on building and simulating a basic analog circuit: the **Positive Diode Clipper**. Key steps included performing the **ERC Check** (Electrical Rule Check) for connection integrity, generating the final **Netlist**, and successfully executing a **Transient Analysis** to visualize the clipping effect on the output waveform. This established fundamental proficiency in the eSim platform.

2.2 Tutorial 2: CMOS Inverter Design with SKY130 PDK

This tutorial transitioned into custom integrated circuit design using the globally adopted **SKY130 PDK** (130nm technology). The simple yet critical **CMOS Inverter** was used as the design example.

- The full content package, including the **script**, **audio recording**, and **final video**, was completed.
- The demonstration required detailed component selection, specifically using the appropriate **SKY130 PFET** and **NFET** models.
- The simulation setup emphasized crucial VLSI concepts like setting the **Process Corner** (e.g., 'tt' for typical-typical) in the Device Modeling tab to ensure realistic performance analysis.
- The final transient analysis successfully demonstrated the fundamental inverted input-output behavior of the CMOS device.

2.3 Tutorial 3: Hierarchical Subcircuit Design with SKY130 PDK

This module focused on hierarchical design principles, extending the CMOS inverter from Tutorial 2 into a reusable block.

- The **script** for "Subcircuit of CMOS inverter using SKY130 PDK" was completed.
- The tutorial demonstrated the creation of a reusable **CMOS Inverter Subcircuit** by importing an existing schematic, defining external **ports** (VDD, VIN, GND, VOUT), and generating a simplified **Symbol** using the Symbol Editor.
- The final section included running a simulation using a predefined **SKY130 Test Circuit** (`avsdspamp_3v3_SKY130`) available in the eSim libraries, showcasing how to efficiently reuse contributed open-source designs.

2.4 Tutorial 4: Foundational Setup of IHP Open PDK Environment

As a prerequisite for advanced IHP-based tutorials, this module addressed the complex command-line setup for the **IHP Open PDK** on the Ubuntu operating system.

- The complete **script** detailing the installation procedure was written.
- Crucial supplementary files were developed, including the **commands.odt** file, containing terminal commands to run the dependency script (**requirements.sh**).
- Technical focus areas included compiling **Ngspice with OSDI** (Open Source Device Interface) support and installing the **OpenVAF** binary, both necessary for advanced model compilation.
- This process also involved setting persistent **environment variables** (like `PDK_ROOT` and `KLAYOUT_PATH`) to ensure the operating system correctly locates the PDK resources.

2.5 Tutorial 5: IHP Subcircuit Creation and Netlist Editing

Building upon the previous setup, this tutorial integrated the IHP PDK environment with hierarchical design, a core skill for complex chip design.

- The **script** was written to guide users through designing an IHP-based CMOS inverter and then encapsulating it as a reusable **subcircuit**.

- A key technical challenge addressed was the necessary manual editing of the generated **Ngspice netlist (.cir.out)** to replace generic eSim device models with the specific **IHP High Voltage (HV) models** and link the IHP library path.
- The subcircuit was then tested by creating a symbol and using it in a test bench circuit, confirming the principles of **Hierarchical Design** and utilization of the ‘X’ (subcircuit) model prefix.

2.6 Project Workflow and Quality Assurance Log

The delivery of these tutorials required a rigorous, iterative workflow, often involving complex debugging and cross-platform verification, especially when dealing with the open-source nature of the PDKs.

- **Environment Setup and Verification:** The initial phase involved establishing the virtual machine environment (Ubuntu 20.04/eSim 2.4 installation) and dedicated effort to manually write and verify all terminal commands for the complex **Tutorial 4 setup** (IHP PDK/Ngspice OSDI compilation).
- **Iterative Script Development:** All tutorial scripts underwent multiple cycles of revision, modification, and integration of assignments, with specific attention paid to time measurements to ensure the final audio/video length was suitable for the Spoken Tutorial format.
- **Technical Debugging and Troubleshooting:** Significant effort was dedicated to resolving technical issues, including:
 - Debugging persistent eSim 2.4 platform inconsistencies within the VirtualBox environment.
 - Troubleshooting and resolving a technical issue encountered on the **eSim on Cloud** website during content verification.
 - Rigorously performing the **cross-verification** of all IHP PDK installation commands through complete system reinstallation and multiple testing runs.
- **Final Media Production:** All final deliverables, including the completed **scripts, slides, and separate audio/video recordings**, were submitted for final review, ensuring all content was pedagogically sound and technically accurate.

Chapter 3

Conclusion and Learning Outcomes

3.1 Conclusion

This internship successfully delivered a complete suite of educational content bridging the gap between open-source EDA tools and industry-standard PDKs. The work directly contributes to the FOSSEE mission by providing accessible training in complex VLSI simulation techniques. The complete documentation of the IHP PDK setup and the practical demonstration of hierarchical design using both SKY130 and IHP models serve as foundational assets for the eSim community.

3.2 Professional and Technical Outcomes

- **Technical Proficiency:** Achieved deep operational knowledge of the **eSim-Ngspice-KiCad toolchain** and proficiency in advanced PDK concepts, including **Process Corners** and **Ngspice netlist manipulation**.
- **Documentation Mastery:** Developed robust skills in creating structured, accurate technical scripts and documentation compliant with the strict **Spoken Tutorial guidelines**.
- **VLSI Concepts:** Solidified practical understanding of **CMOS inverter analysis**, **Analog Clipper circuits**, and critical VLSI design principles like **Hierarchical Design** and **Netlist Integrity**.

Reference

- FOSSEE Project, IIT Bombay: <https://fossee.in/>
- Spoken Tutorial Project: <https://spoken-tutorial.org/>
- eSim Circuit Simulation Tool: <https://esim.fossee.in/>
- IHP Open PDK GitHub Repository
- SKY130 PDK Documentation