DVD Assignment – 1

Generation of PVT Varied Dataset on a 45nm-HP Node

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***Abstract*— This report delineates the process of generating datasets pivotal for training regression-based machine learning models, serving as a foundational step for Project-2. The dataset generation process entails two primary components: the creation of Process, Voltage, and Temperature (PVT) combinations through sampling from predetermined distributions, and the utilization of these combinations to simulate circuits, with Static Leakage power and Propagation delay serving as target variables.**

I. Contributions

Ashish: Ashish played a key role in the project by contributing to the generation of netlists, which are essential for defining the circuit structures. Additionally, he was instrumental in developing Python scripts tailored to the specific task of generating datasets focusing on the propagation delay from low to high values.

Mayank: Mayank's contributions were vital to the project's success. He actively participated in the generation of netlists, which laid the foundation for simulating circuit behavior. Moreover, he dedicated his efforts to developing Python scripts tailored to the generation of datasets with a focus on propagation delay from high to low values.

Pronoy: Pronoy made valuable contributions to the project by specializing in Python scripting for the generation of datasets related to leakage power. His expertise in scripting languages and understanding of circuit simulation processes were instrumental in developing scripts that accurately captured leakage power variations under different conditions.

Vedant: Vedant played a pivotal role in the project by focusing on the generation of netlists for all three circuits under study. His expertise in circuit design and simulation enabled him to create accurate and efficient netlists that accurately represented the circuit structures.

II. Introduction

This assignment involves generating datasets from simulations to train regression-based machine learning models. It is a pre-requisite step for Project-2. Dataset generation comprises of two main parts, generating Process, Voltage and Temperature (PVT) combinations by sampling these variables from pre-decided distributions and using these values to simulate circuits.

In electronic design automation (EDA), the ability to predict and optimize circuit performance under varying conditions is indispensable. However, acquiring empirical data to train predictive models necessitates exhaustive experimentation, often proving time-consuming and resource intensive. Herein lies the significance of simulation-based dataset generation, offering a cost-effective and efficient alternative to empirical methods. By leveraging simulations to emulate real-world scenarios and systematically vary PVT parameters, this approach facilitates the creation of diverse and representative datasets crucial for training machine learning models.

The primary objective of this assignment is twofold: firstly, to generate datasets reflective of real-world circuit behavior under varying PVT conditions, and secondly, to prepare these datasets for subsequent utilization in training regression-based machine learning models. The scope encompasses the meticulous orchestration of PVT combinations, the simulation of circuit behavior using these combinations, and the measurement of Static Leakage power and Propagation delay, which serve as the target variables in the resulting dataset.

Throughout this process, emphasis is placed on measuring the Static Leakage power and Propagation delay of the circuit, which serve as pivotal target variables within the dataset. This introduction provides an overview of the objectives, methods, and significance of the dataset generation process, paving the way for a comprehensive exploration in subsequent sections of this report.

III. Instructions

A. Objective:

To adhere to the prescribed requirements of the assignment, a meticulous approach to dataset generation was undertaken. The following sections detail the methodology employed in generating 10,000 samples using the 45nm-HP (High Performance) PTM file, ensuring the appropriate distribution of Process, Voltage, and Temperature (PVT) values to satisfy Monte-Carlo distribution criteria. The simulation platform utilized for this task was NGSPICE, a versatile tool for electronic circuit simulation.

B. Determining PVT Distributions:

A crucial aspect of dataset generation is the determination of PVT distributions that accurately reflect real-world conditions while encompassing the specified ranges. The temperature range was set from -55 to 125 Celsius, following a uniform distribution to capture a broad spectrum of operating conditions. Nominal voltage was established at 1V, with uniform variations of ±10% to emulate practical voltage fluctuations.

In line with the Monte Carlo distribution principles, process parameters were varied around nominal standards derived from the 45nm-HP PTM file. Specifically, parameters such as toxe, toxm, toxref, tox par, ndep, and xj for both PMOS and NMOS transistors were adjusted with a $\pm 3\sigma$ variation, where σ represents the standard deviation calculated as the mean divided by 30. This methodology ensured a diverse yet realistic representation of process variations.

For delay considerations, cqload variations ranging from 0.01f to 5f were incorporated using a uniform distribution. This wide range of values accounts for different load conditions, capturing variations in circuit performance across diverse scenarios.

C. Simulation setup using NGSPICE

NGSPICE was employed as the simulation platform due to its robust capabilities in circuit simulation and its compatibility with SPICE netlists. The SPICE netlists for the standard gates (NOR2, NAND2, and NOT) were constructed according to the provided specifications. These netlists served as the basis for simulating the circuits under varying PVT conditions.

D. Generating PVT Samples

To generate the required 10,000 samples, PVT values were systematically swept to cover the defined ranges while adhering to the Monte-Carlo distribution. Each sample encompassed a unique combination of Process, Voltage, and Temperature values, ensuring a diverse dataset representative of real-world scenarios.

E. Data Collection and storage

Throughout the simulation process, data on Static Leakage power and Propagation delay of the circuits were collected. These metrics served as the target variables for the dataset. Leakage power was measured through DC analysis, while delay was assessed via transient analysis, employing PWL signals as inputs.

F. Resulting dataset Structure

The resulting dataset adhered to the specified parameters and distributions, comprising 10,000 samples with associated leakage and delay data. Each sample encapsulated the unique PVT combination along with corresponding circuit performance metrics, facilitating subsequent analysis and machine learning model training.

IV. Methodology

The implementation methodology outlined below delineates the step-by-step process followed to execute the dataset generation procedure, encompassing the construction of SPICE netlists, generation of PVT distributions, and subsequent simulation to generate leakage and delay datasets.

A. Construction of SPICE Netlists

The initial phase of the implementation involved the construction of SPICE netlists for three standard gates: NOR2, NAND2, and NOT. The netlists were created according to the provided specifications, as depicted in Figures 1, 2, and 3. These netlists served as the basis for simulating the behavior of the standard gates under varying PVT conditions.

B. Generation of PVT Distributions

To generate a comprehensive dataset, 10,000 PVT distributions were systematically generated within the predefined bounds. Each distribution encapsulated unique combinations of Process, Voltage, and Temperature values. It is important to note the cautionary instruction regarding the generation of samples based on input combinations. For instance, if an input gate has four combinations (00, 01, 10, 11), four samples were generated for each PVT value to ensure thorough coverage of input scenarios.

C. SPICE Simulation for Leakage and Delay Dataset Generation

Using the constructed SPICE netlists, the next step involved sweeping across the generated PVT samples to simulate the behaviour of the standard gates under varying conditions. Two key metrics, Static Leakage power, and Propagation delay were measured during the simulation process.

- **Leakage Analysis:** For leakage power estimation, cqload was dropped, and DC analysis was performed.

This enabled the calculation of Static Leakage power under different PVT conditions.

- **Delay Analysis:** To assess propagation delay, DC inputs were dropped, and transient analysis was conducted using PWL signals as inputs, considering a single PVT at a time. This facilitated the measurement of delay metrics such as delay lh nodea, delay hl nodea, delay hl nodeb, and delay hl nodeb for gates with two inputs.

D. Dataset Compilation

The resulting dataset comprised 10,000 samples, each representing a unique PVT combination. For leakage analysis, the dataset contained associated leakage values, while delay analysis yielded delay metrics corresponding to each input combination. These leakage and delay metrics were concatenated into the dataset, resulting in a comprehensive dataset structure like Table 1.

$$10k\ pvt * 2^{no.of\ inputs}$$

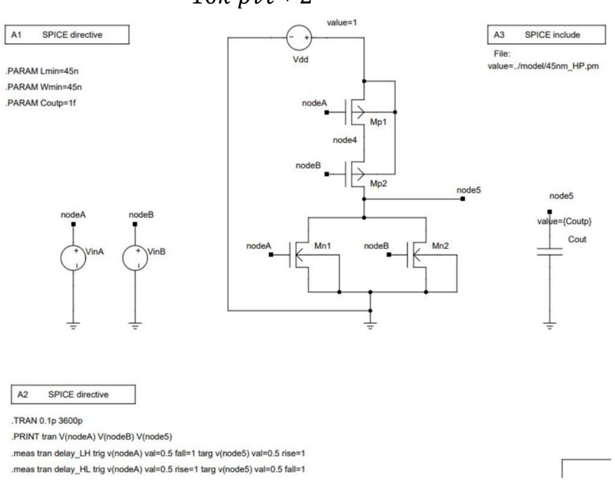

Fig 1. NOR Gate

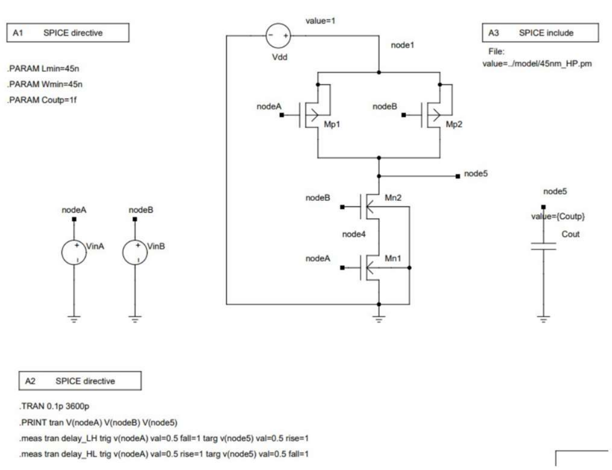

Fig 2. NAND Gate

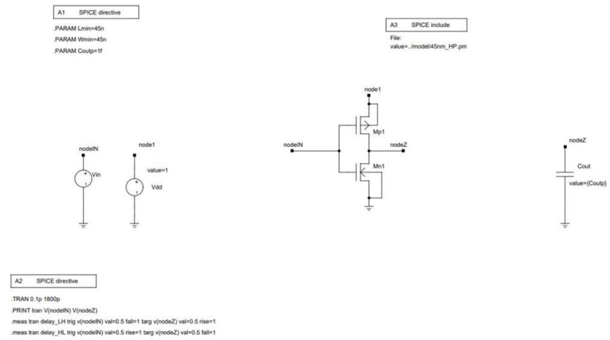

Fig 3. NOT Gate

Vin_A	Vin_B	temp	pvdd	cqload	lmin	wmin	toxe_n	toxm_n	toxref_n	toxe_p	toxm_p	toxref_p	toxp_par	xj_n	xj_p	ndep_n	ndep_p
0	0	120	0.83	2.61E-15	2.15E-08	2.32E-08	8.25E-10	1.07E-09	1.09E-09	1.02E-09	1.07E-09	1.09E-09	1.07E-09	6.99E-09	7.09E-09	5.50E+18	4.38E+18
0	1	120	0.83	2.61E-15	2.15E-08	2.32E-08	8.25E-10	1.07E-09	1.09E-09	1.02E-09	1.07E-09	1.09E-09	1.07E-09	6.99E-09	7.09E-09	5.50E+18	4.38E+18
1	0	120	0.83	2.61E-15	2.15E-08	2.32E-08	8.25E-10	1.07E-09	1.09E-09	1.02E-09	1.07E-09	1.09E-09	1.07E-09	6.99E-09	7.09E-09	5.50E+18	4.38E+18
1	1	120	0.83	2.61E-15	2.15E-08	2.32E-08	8.25E-10	1.07E-09	1.09E-09	1.02E-09	1.07E-09	1.09E-09	1.07E-09	6.99E-09	7.09E-09	5.50E+18	4.38E+18
0	0	-34	0.75	6.17E-16	2.09E-08	2.25E-08	8.10E-10	1.02E-09	1.06E-09	1.02E-09	1.13E-09	1.04E-09	1.11E-09	7.29E-09	7.26E-09	5.48E+18	4.32E+18
0	1	-34	0.75	6.17E-16	2.09E-08	2.25E-08	8.10E-10	1.02E-09	1.06E-09	1.02E-09	1.13E-09	1.04E-09	1.11E-09	7.29E-09	7.26E-09	5.48E+18	4.32E+18
1	0	-34	0.75	6.17E-16	2.09E-08	2.25E-08	8.10E-10	1.02E-09	1.06E-09	1.02E-09	1.13E-09	1.04E-09	1.11E-09	7.29E-09	7.26E-09	5.48E+18	4.32E+18
1	1	-34	0.75	6.17E-16	2.09E-08	2.25E-08	8.10E-10	1.02E-09	1.06E-09	1.02E-09	1.13E-09	1.04E-09	1.11E-09	7.29E-09	7.26E-09	5.48E+18	4.32E+18

Table 1 Example values for PVT distributions

CONCLUSION

In conclusion, this assignment has successfully addressed the critical task of generating datasets essential for training regression-based machine learning models. By meticulously following the outlined methodology, datasets encompassing diverse Process, Voltage, and Temperature (PVT) combinations have been created for three standard cells: NOT, NAND2, and NOR2. Leveraging the 45nm-HP PTM file and NGSPICE simulations, 10,000 samples were generated, adhering to the specified PVT distributions, and capturing variations in Static Leakage power and Propagation delay.

Through the construction of SPICE netlists, systematic generation of PVT distributions, and subsequent simulation of circuit behaviour, the assignment has achieved its objectives. The resulting dataset, structured to include leakage and delay metrics, holds immense value for the training and evaluation of machine learning models. It provides a comprehensive understanding of circuit performance under diverse operating conditions, laying a solid foundation for subsequent analysis and model training in Project-2.

Overall, this assignment underscores the importance of simulation-based dataset generation in facilitating machine learning model development within the realm of electronic design automation. By adhering to rigorous methodologies and leveraging advanced simulation tools, it has paved the way for future advancements in circuit optimization and predictive modelling.

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