Charge Pump Based Stabilized Power Supply

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Agenda

PEARL
מעבדה לאלקטרוניקת הספק
ואנרגיות מתחדשות
ע"ש גיא סלע

- project’s goal
- description of the unit
- Alternative solution
- Future planning

Background: Introduction

In VLSI components, the demand for varied power sources and dynamic voltage adjustments is crucial. Current solutions, notably Low Dropout Voltage regulators (LDO), face limitations in handling multiple low-current suppliers efficiently.

Limitations of Current Solutions*:* LDO regulators increase component count, leading to larger footprints and higher power consumption, hindering advancements in miniaturization and energy efficiency.

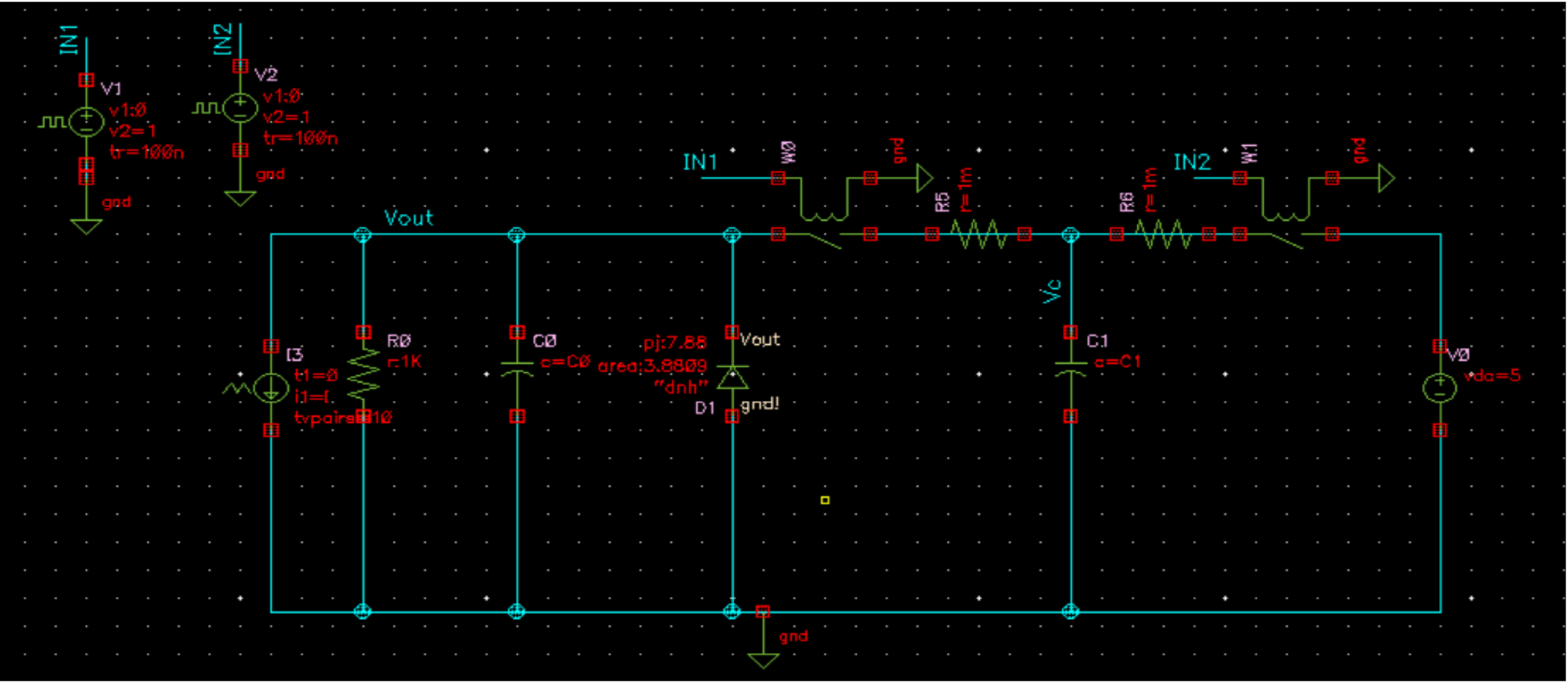
Emphasizing the Need for Innovation

This project addresses the shortcomings of traditional solutions by proposing on-chip charge pump circuits. This shift not only reduces component count but also enhances power efficiency, aligning with industry trends and contributing to the evolution of VLSI technology.

Objectives and Scope:

Our project focuses on revolutionizing power supply solutions in VLSI components. The primary goal is to implement three distinct charge pump circuits and integrate a sophisticated voltage stabilization control system. This undertaking is geared towards addressing the limitations of traditional regulators and enhancing the efficiency of power supply systems in the realm of Very Large Scale Integration.

Description of the Algorithm



Analysis of the circuit

$the\ charge\ of\ the\ input\ capacitor:$

$$Q_c = c_{in} * V_{in} \qquad for\ the\ first\ stage$$

$$Q_c' = c_{in} * V_{out} \qquad for\ output\ capacitor$$

$from\ the\ circuit\ we\ see\ that:$

$$I_{out} = \Delta Q * f \qquad where\ f\ represent\ the\ frequency$$

$$I_{out} = f * c(v_i - v_{out})$$

$$v_{out} = v_i - \frac{1}{f * c} I_{out} \Rightarrow R_e = \frac{1}{fc} \rightarrow v_{out} = v_i - R_e i_{out}$$

Analysis of the circuit

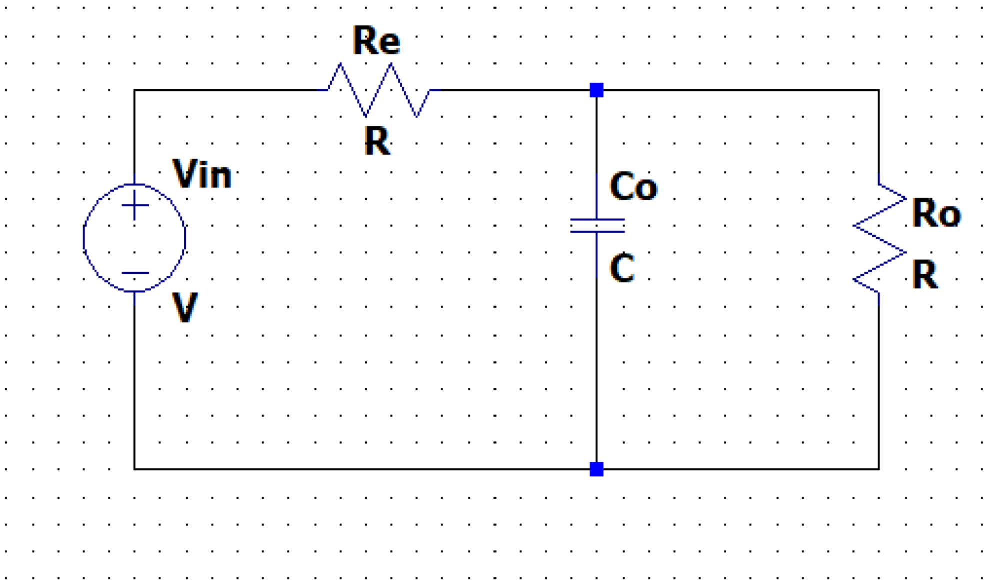
We can also model our converter with average circuit

$$Vo = V_i * \frac{1}{1+\frac{R_e}{R}}$$

$$p_{LOSS} = \frac{(v_i - v_o)^2}{R_e} = i_0^2 * R_e$$

$$p_{out} = i_0^2 * R$$

$$\%\eta = \frac{100}{1+\frac{R_e}{R}}$$



Voltage ripple

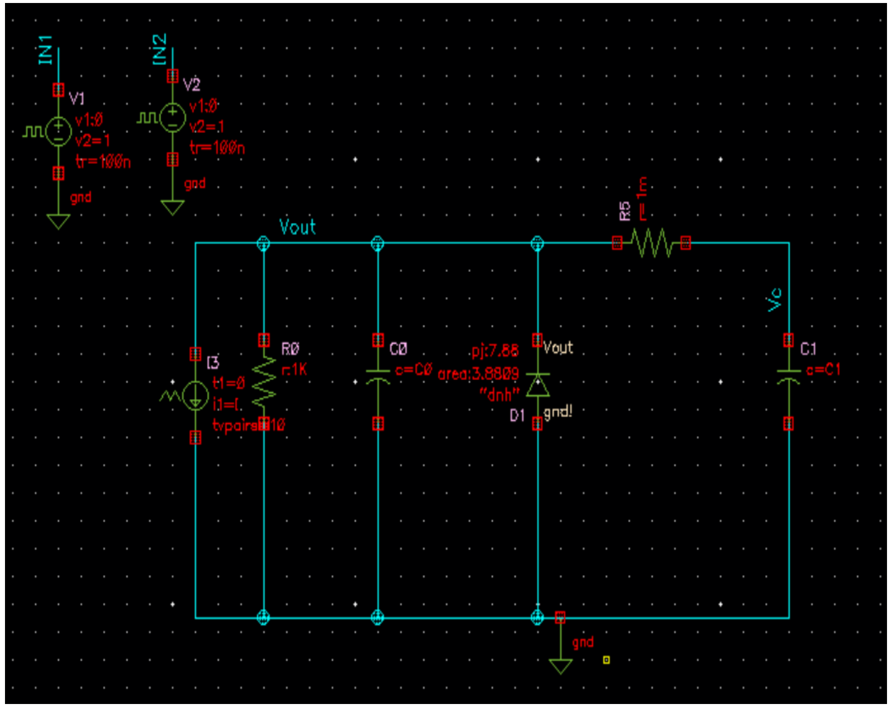
$$\Delta Q_0 \cong \Delta Q = c * V_{in} - CV_o$$

$$\Delta V_o = \frac{1}{C_0} * C(v_{in} - v_{out}) = \frac{1}{c_0} * cI_0R_e$$

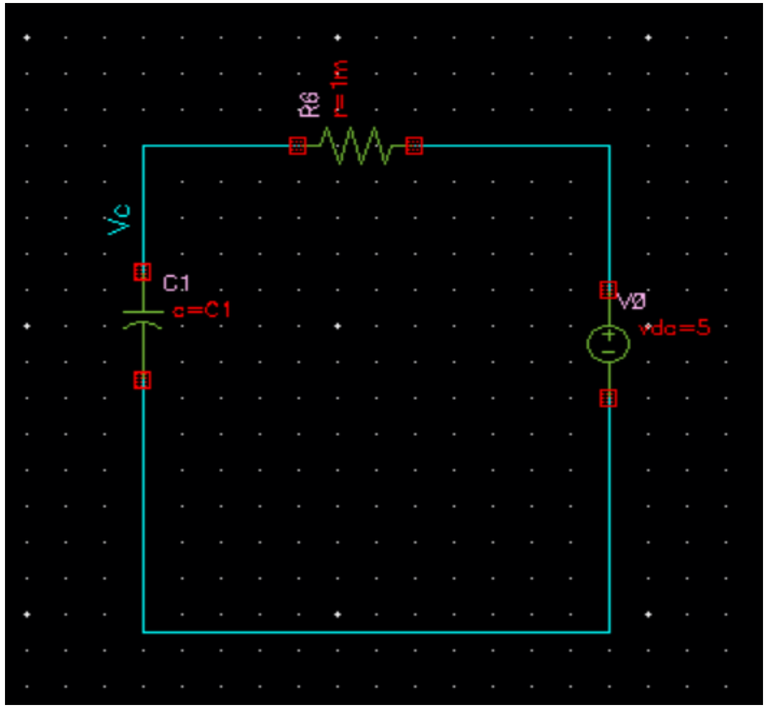
$$\Delta V_0 = \frac{I_0}{fC_0}\ peak\ to\ peak\ voltage\ ripple$$

Description of the Algorithm

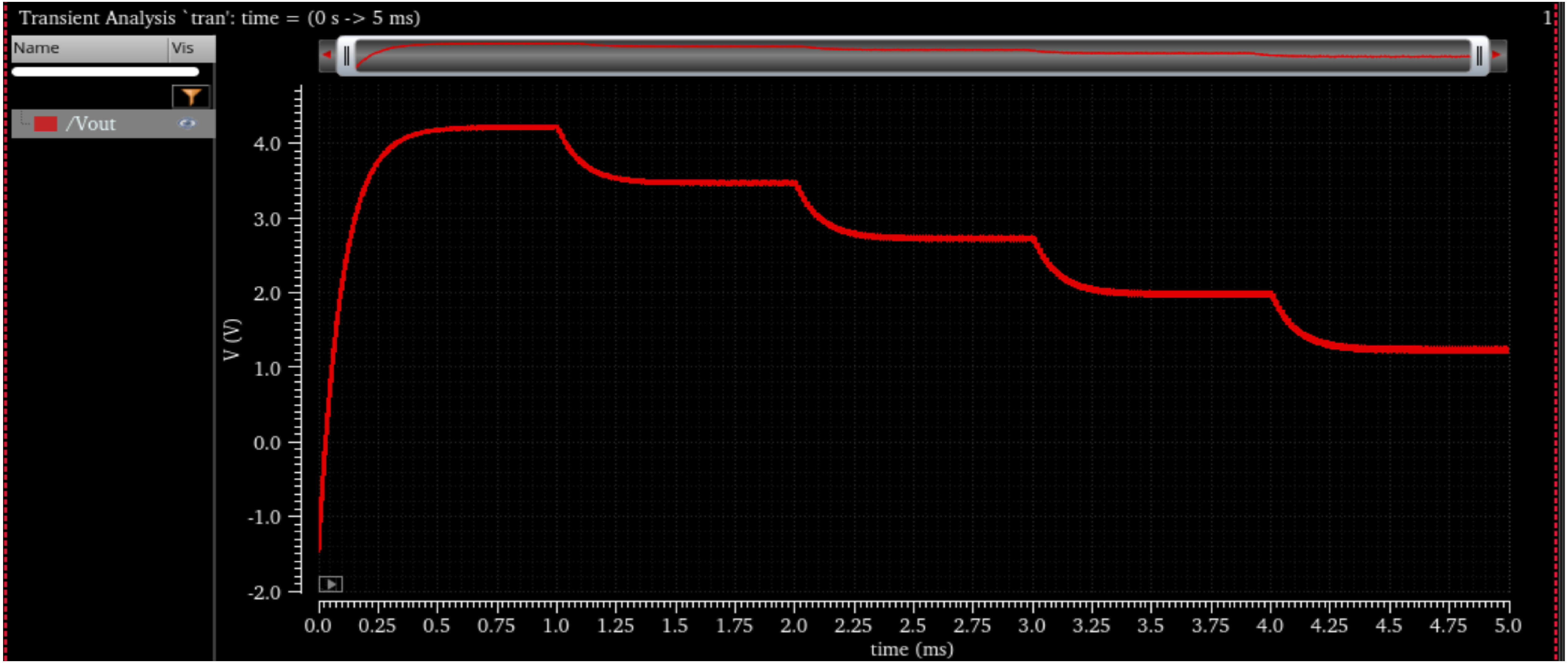
Second stage



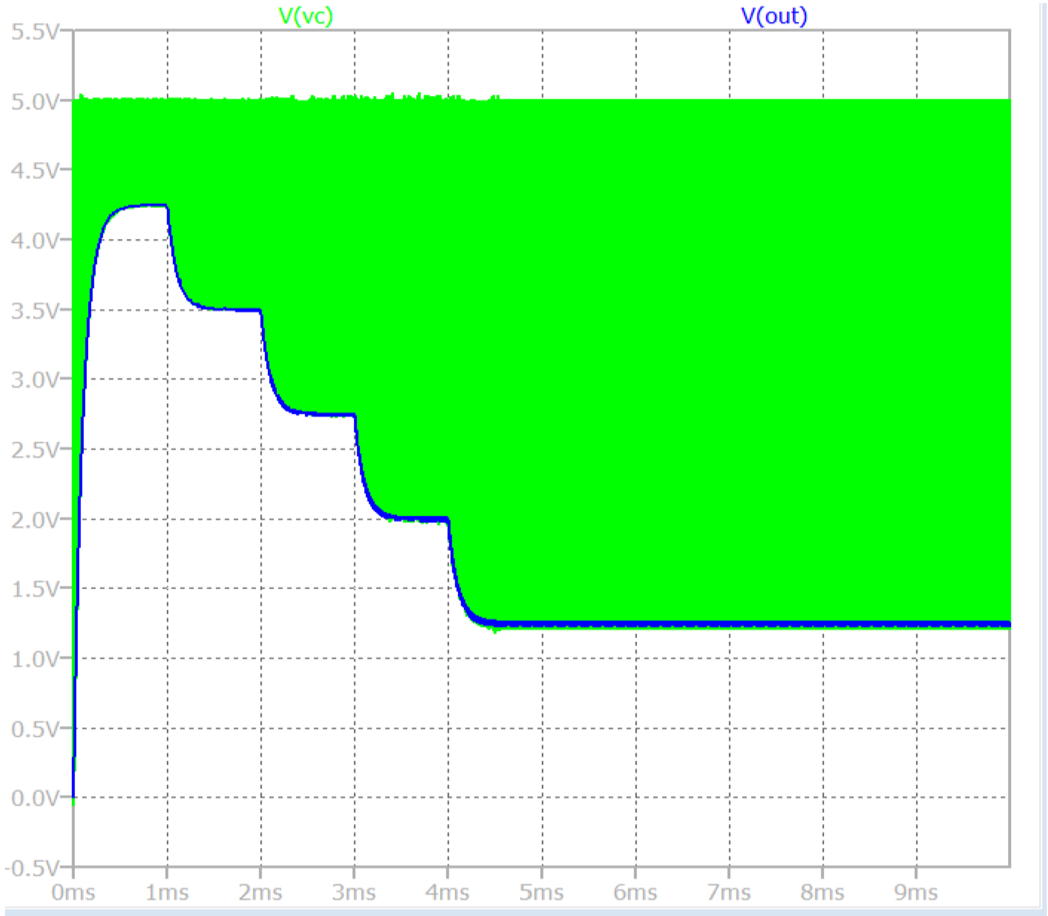
FIRST stage

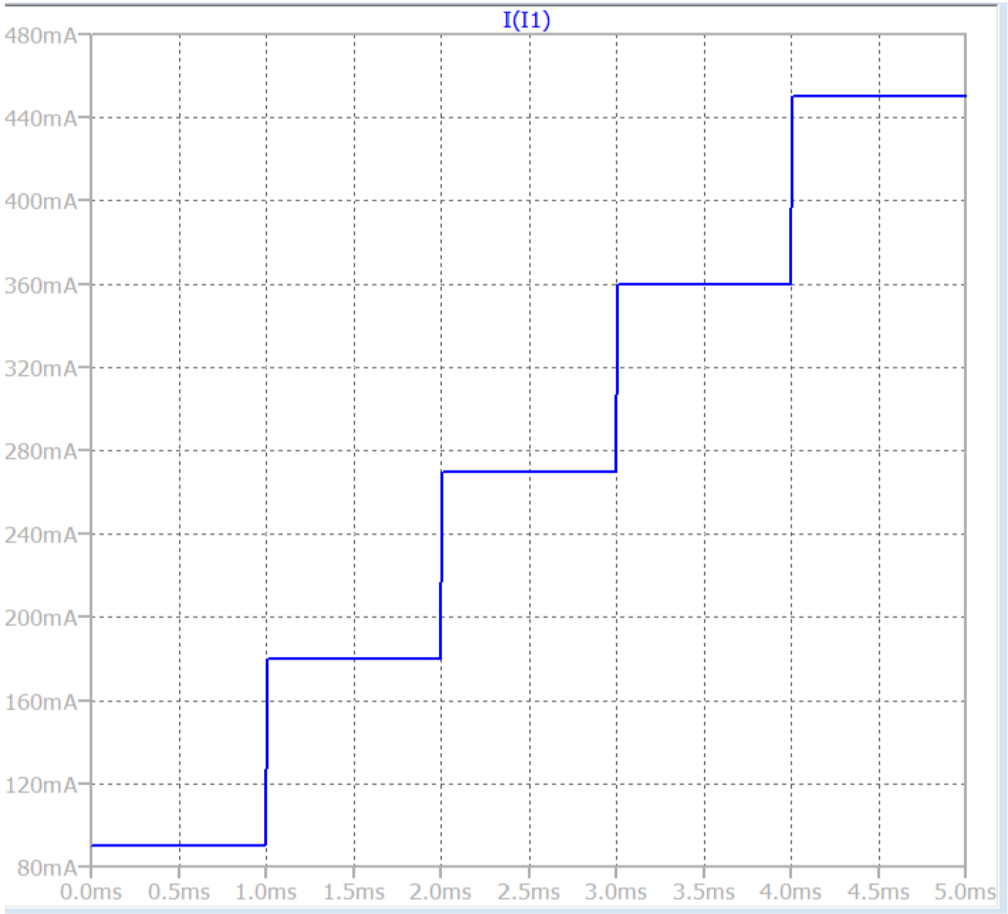


Output voltage simulation

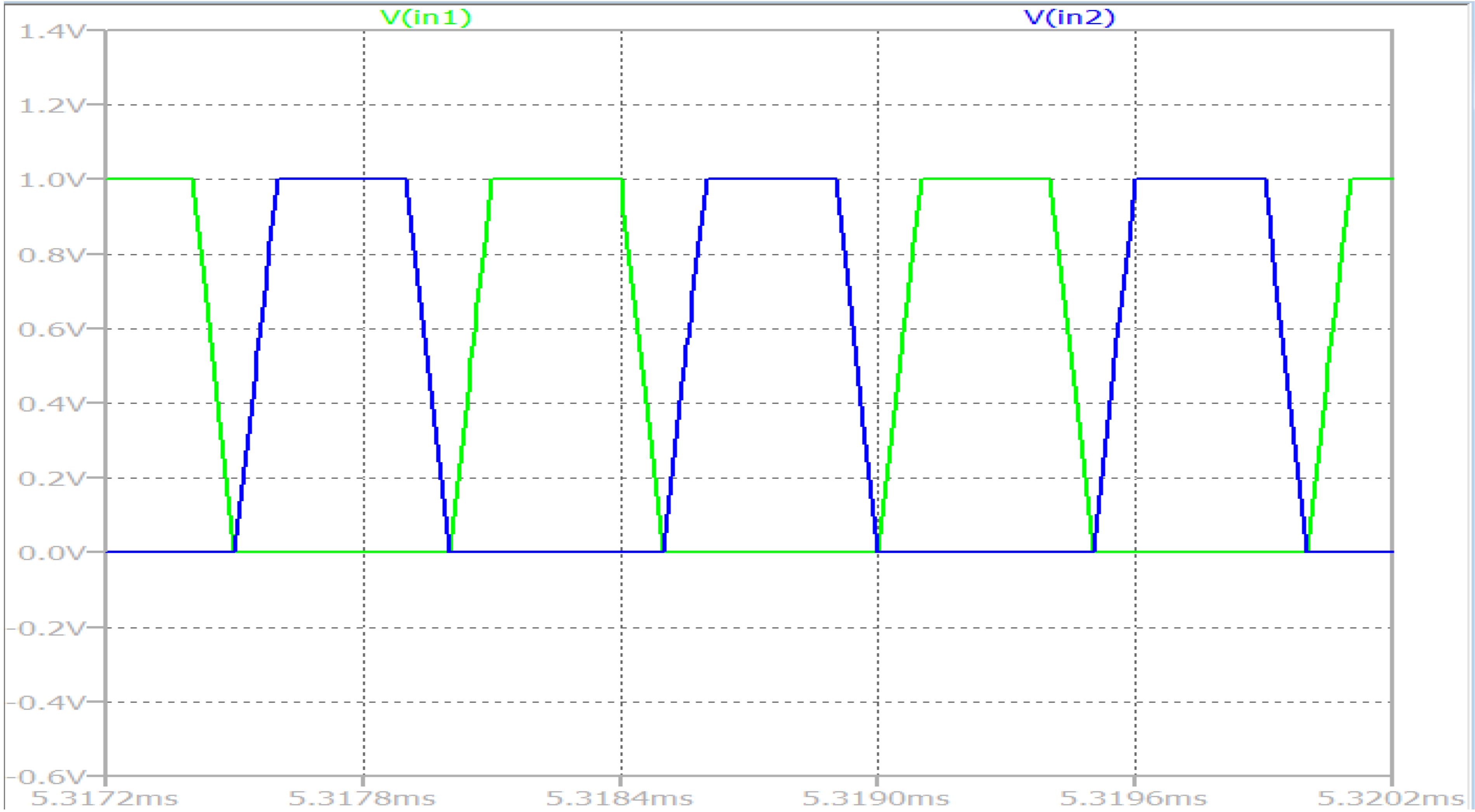


simulations





PWM

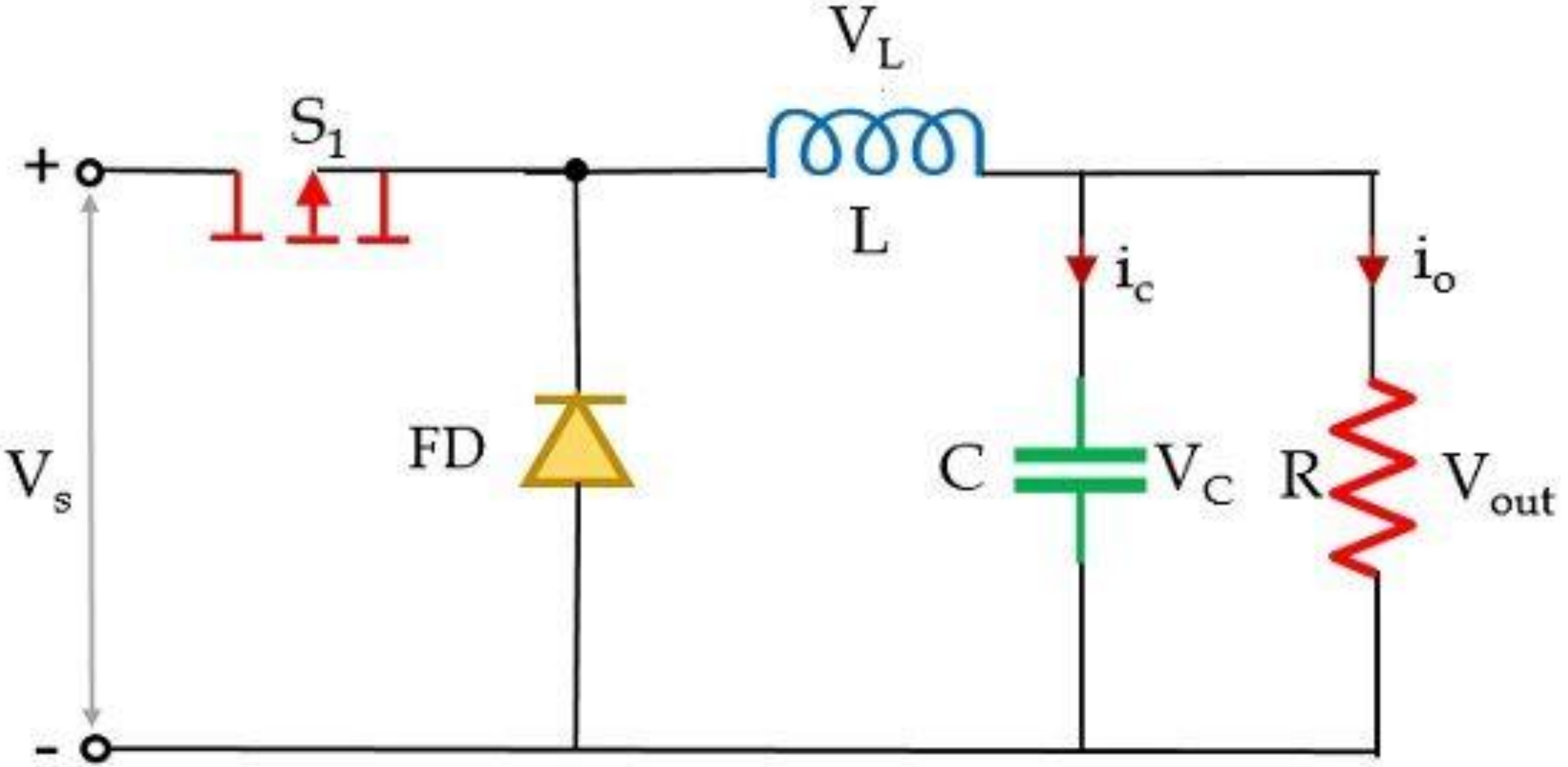


V(in1)
V(in2)
1.4V
1.2V
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
-0.2V
-0.4V
-0.6V
5.3172ms
5.3178ms
5.3184ms
5.3190ms
5.3196ms
5.3202ms

Alternative Solutions

Traditionally, Low Dropout Voltage regulators (LDO) have been the go-to solution for power supply in VLSI components. However, their limitations become evident in scenarios requiring multiple low-current suppliers, where increased component count compromises miniaturization and energy efficiency.

Architectural Design of the Selected Solution



Buck Converter

What is the buck converter

A buck converter, also known as a step-down converter, is a type of DC-DC power converter that efficiently transforms a higher input voltage to a lower output voltage. It's a crucial component in electronic devices where different voltage levels are required for different parts of the system. The key components of a buck converter include an input capacitor, an inductor, a switch (usually a transistor), a diode, and an output capacitor.

How it works

Switching Phase (On-state): When the switch (transistor) is in the "on" state, current flows from the input voltage source through the inductor to the load and the output capacitor. The inductor stores energy during this phase.

Freewheeling Phase (Off-state): The switch is turned off, and the inductor discharges its stored energy. The diode allows the current to continue flowing in the circuit, completing the output voltage.

Control and Regulation: The duty cycle of the switch (the ratio of on-time to the total switching period) determines the output voltage. By adjusting the duty cycle, the buck converter can regulate the output voltage.

differences between a buck converter and a charge pump

Efficiency: Buck converters generally offer higher efficiency than charge pumps, especially in applications with higher power requirements.

Complexity: Buck converters are more complex due to the presence of an inductor, but they are also capable of handling higher power levels. Charge pumps are simpler but may not be suitable for high-power applications.

Voltage Regulation: Buck converters provide better voltage regulation since they can maintain a stable output voltage over a wider range of input voltages.

Cost and Size: Charge pumps are often simpler and can be more cost-effective for low-power applications. However, for higher power levels, buck converters may provide a more compact and effcient solution

Status - What Has Been Done

Accomplishments (Wat Has Been Done):

Research and Technology Selection:

Conducted thorough research and selected the 180nm process for charge pump circuit implementation.

Architectural and Circuit Design:

Developed a robust architecture featuring three specialized charge pump circuits and a voltage stabilization control system, tailored for the 180nm process.

Preliminary Simulations:

Executed preliminary simulations to evaluate the designed circuits, showing promising initial **h**results in terms of efficiency and stability.

Future Work (Remaining Tasks and Next Steps):

Detailed Simulations and Optimization:

- Conduct more extensive simulations to refine and optimize circuit performance under varied conditions.

Error Analysis and Fine-tuning:

- Implement error analysis, focusing on operational amplifier offsets. Fine-tune parameters based on simulation outcomes.

Integration Testing:

- Integrate charge pump circuits and the control system, conduct rigorous testing to validate overall performance.

Validation against Specifications:

- Validate the design against project objectives, ensuring alignment with efficiency, stability, and adaptability goals.

Documentation and Reporting:

- Document findings, optimizations, and final parameters. Prepare comprehensive reports for knowledge transfer and potential publications.