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Invited Papers Session 02

Dec. 9, 2021

# Comparison of Three Types of Startup Circuits for Self-biasing MOS Reference Current Sources

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Gunma University

Jedat Inc.

# OUTLINE

- **Research Background**
- **MOS Drain Current Temperature Characteristics**
- **Gunma University (GU) Reference Current Source**
- **Three Types of Startup Circuits**
  - **— Startup Circuit 1**
  - **— Startup Circuit 2 (CMOS inverter usage)**
  - **— Startup Circuit 3 (Capacitor usage)**
- **Conclusion**

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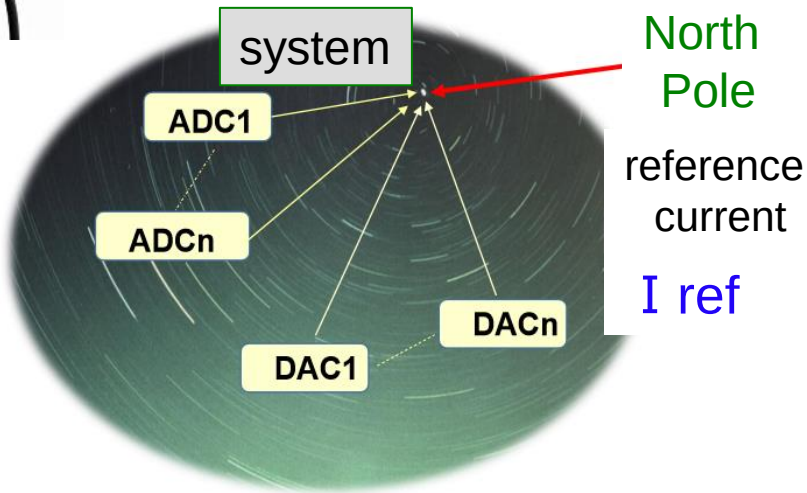
# Research Background

Reliability issues in electronic circuits

- Process
- Voltage
- Temperature




First, we present

**MOS Reference Current Sources**
**Insensitive to Supply Voltage and Temperature**

Next,

**Consider and Compare the Three Types of Startup Circuits**
**in terms of Chip area, Power consumption, and Startup operation certainty.**

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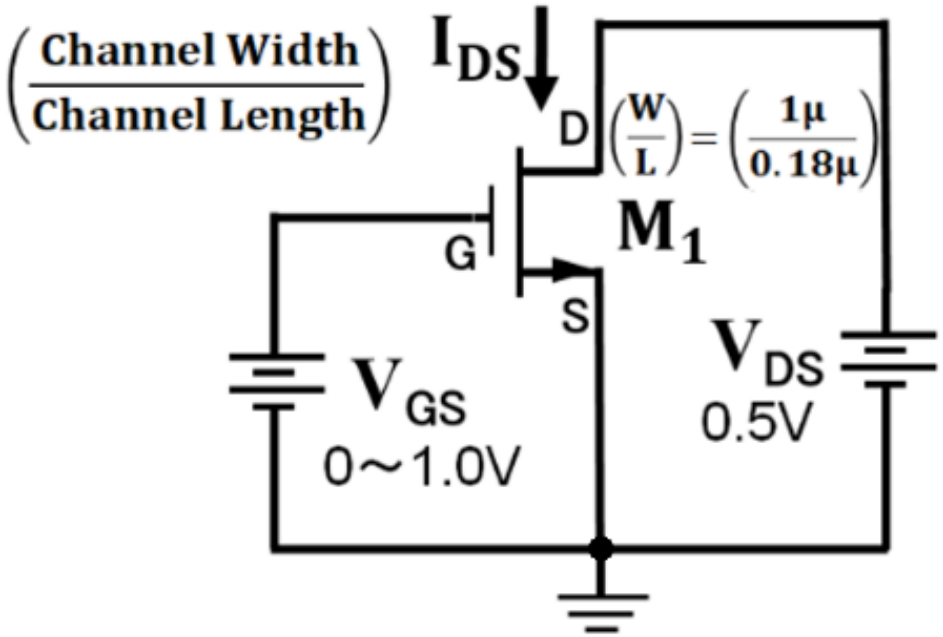
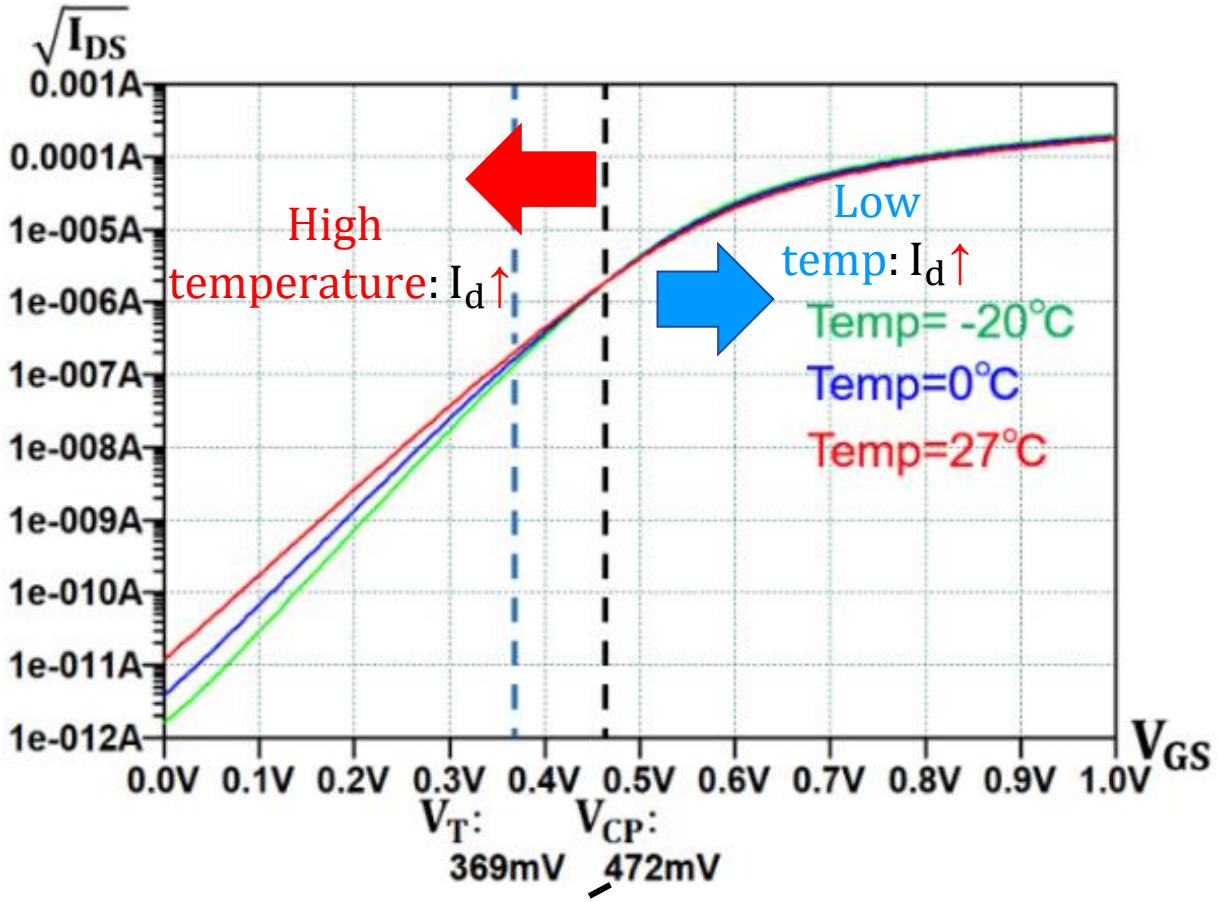
# MOS Drain Current and Gate Voltage

Simulated drain current temperature characteristics




TSMC 0.18μm BSIM3v3 CMOS SPICE parameters




At $V_{CP}$ (472mV): Drain current is fixed against temperature change

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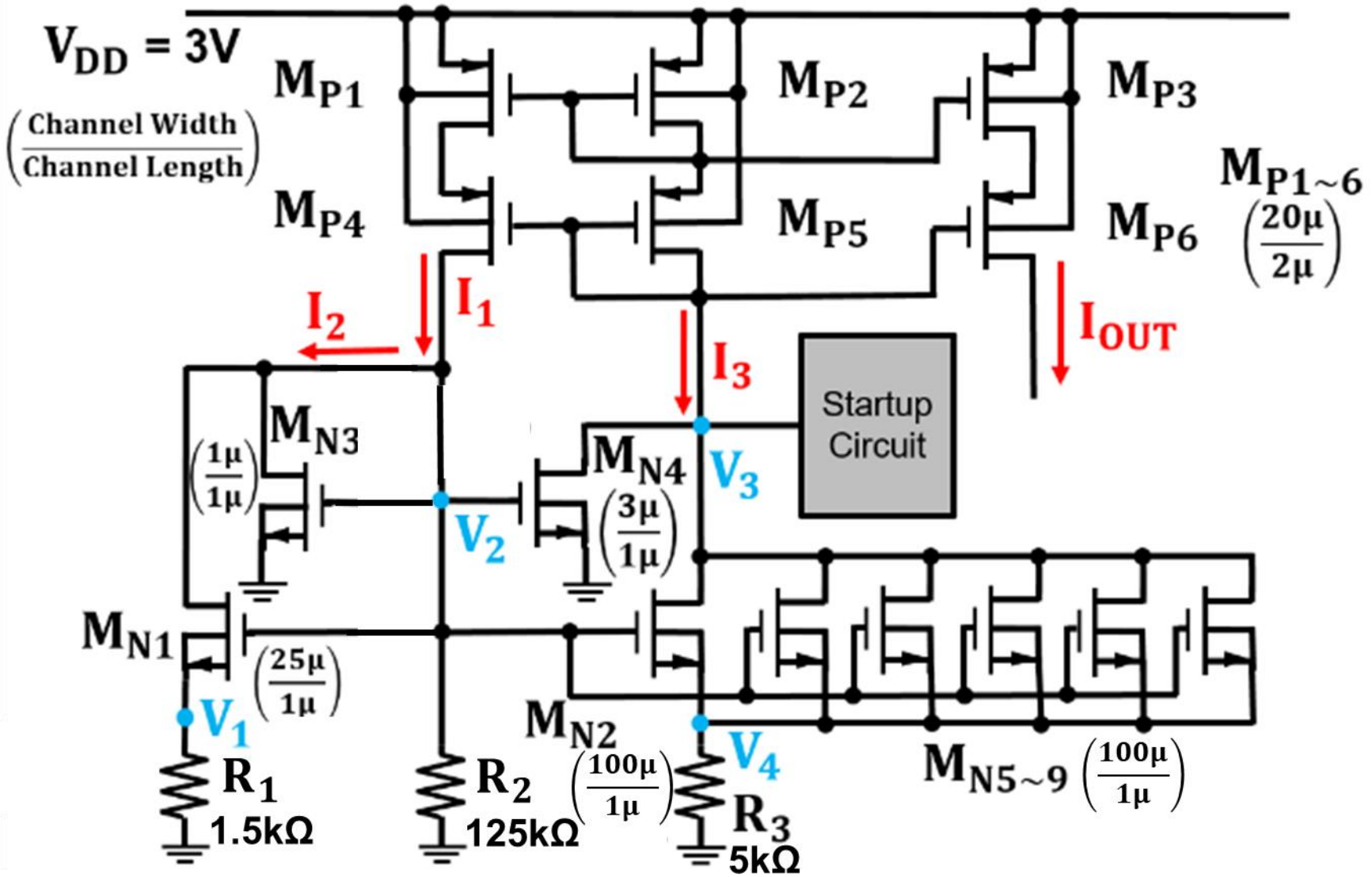
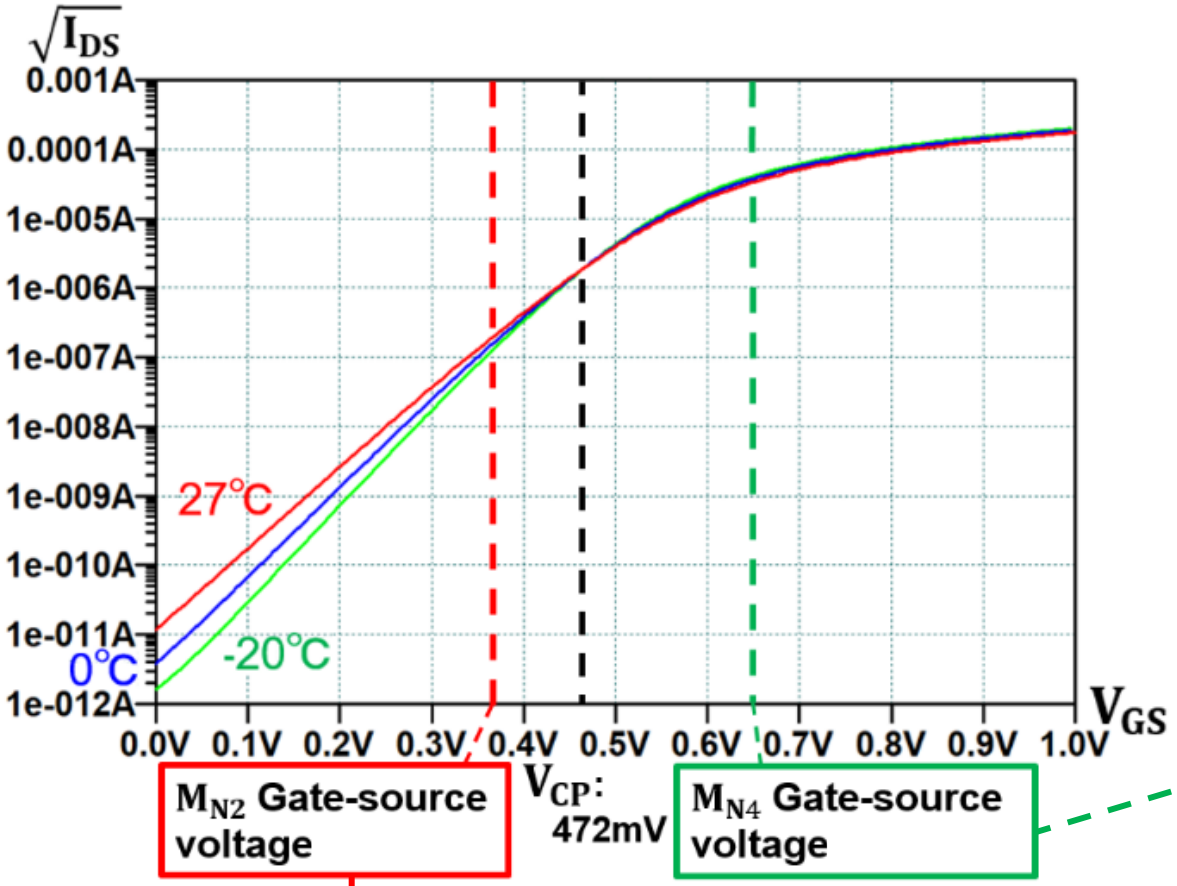
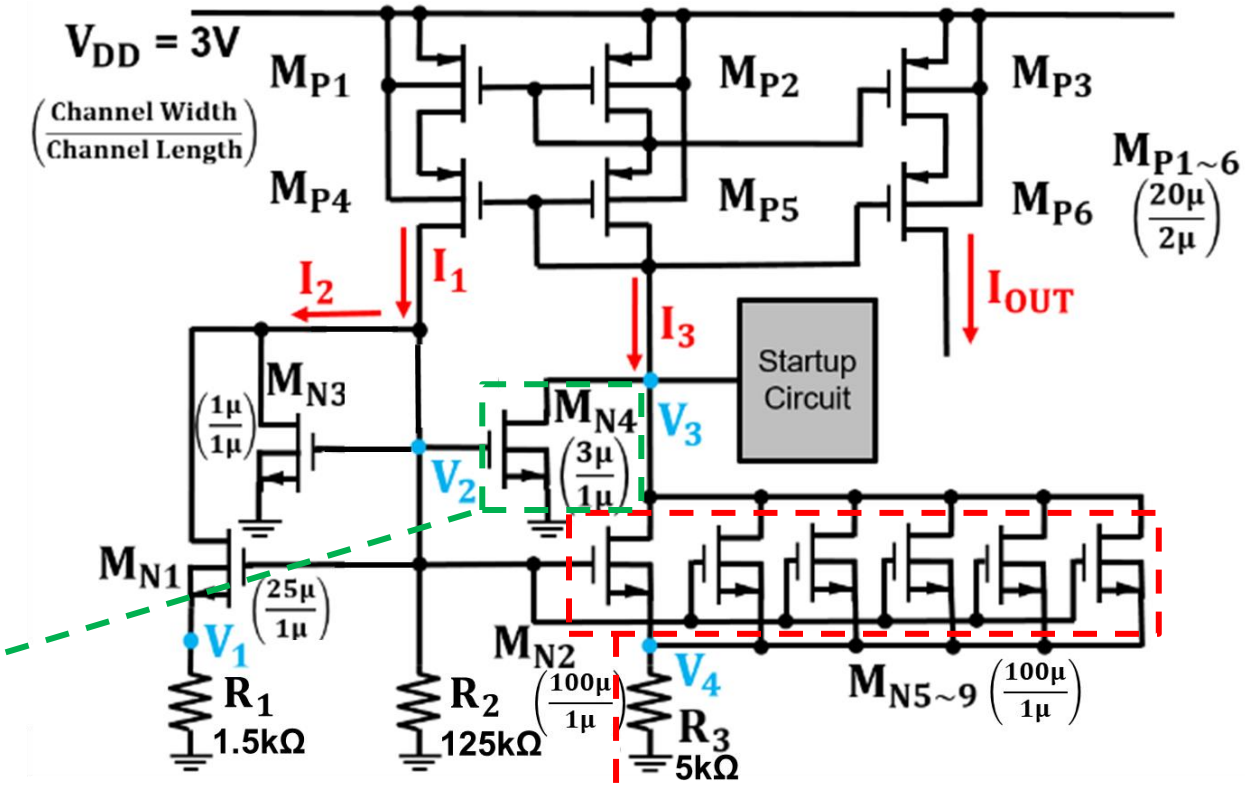
# Gunma University (GU) Reference Current Source

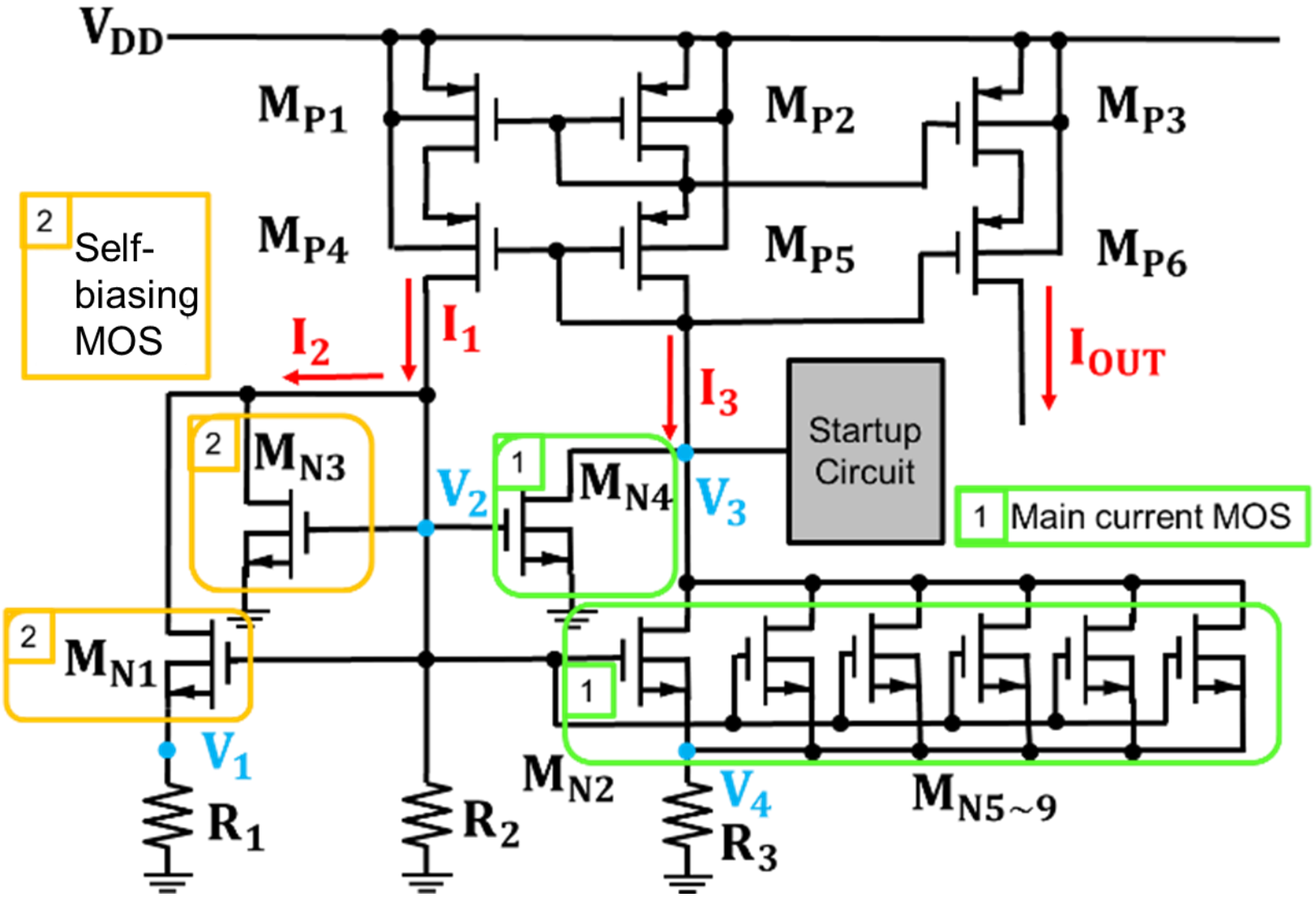


# Temperature characteristic cancellation

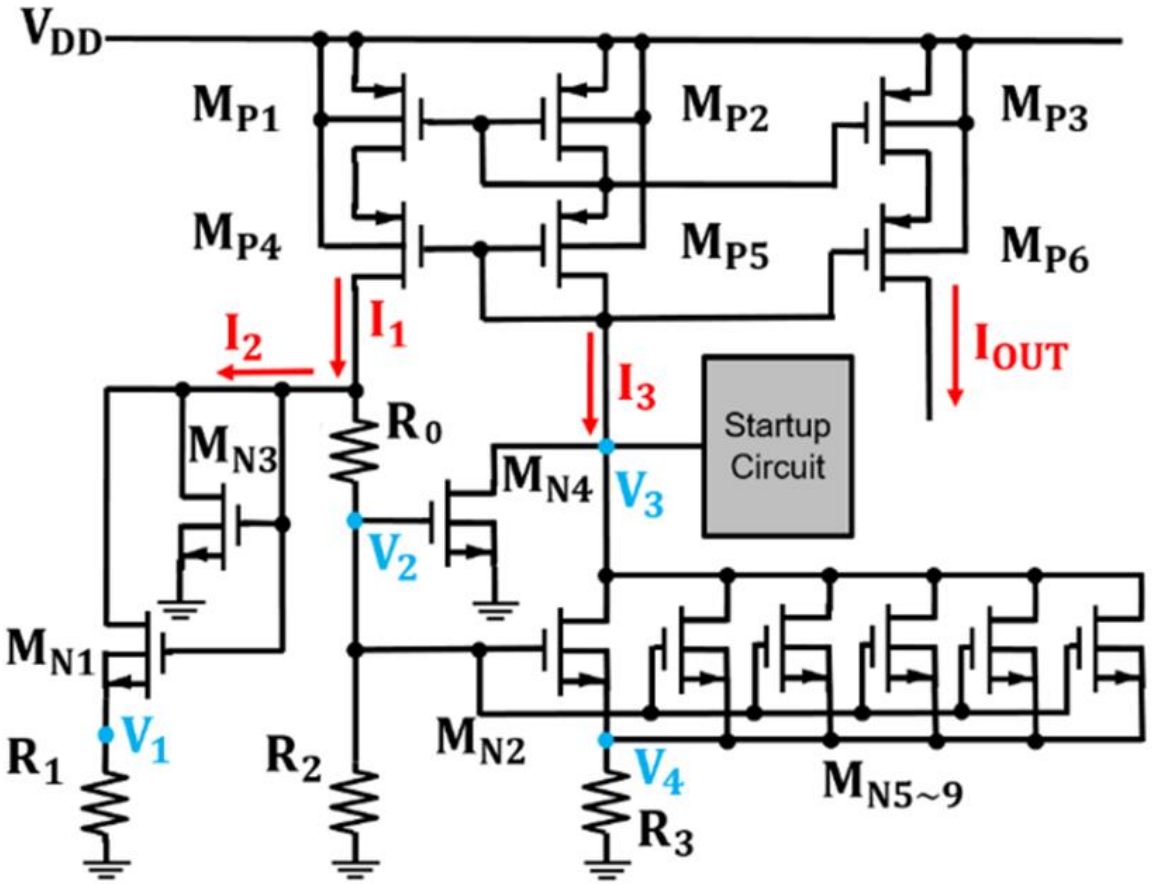


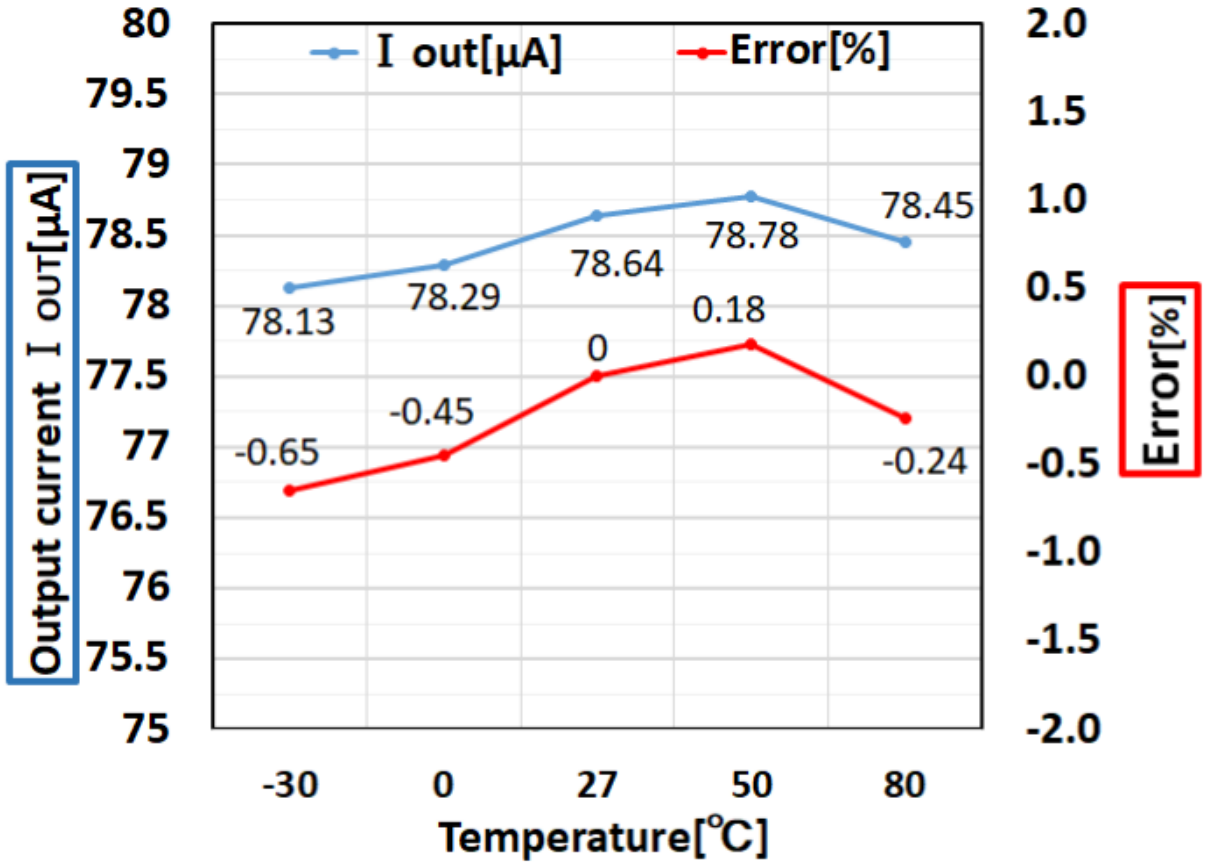



# $V_2$ Suppression by Self-biasing MOS



# Output Current $I_{OUT}$



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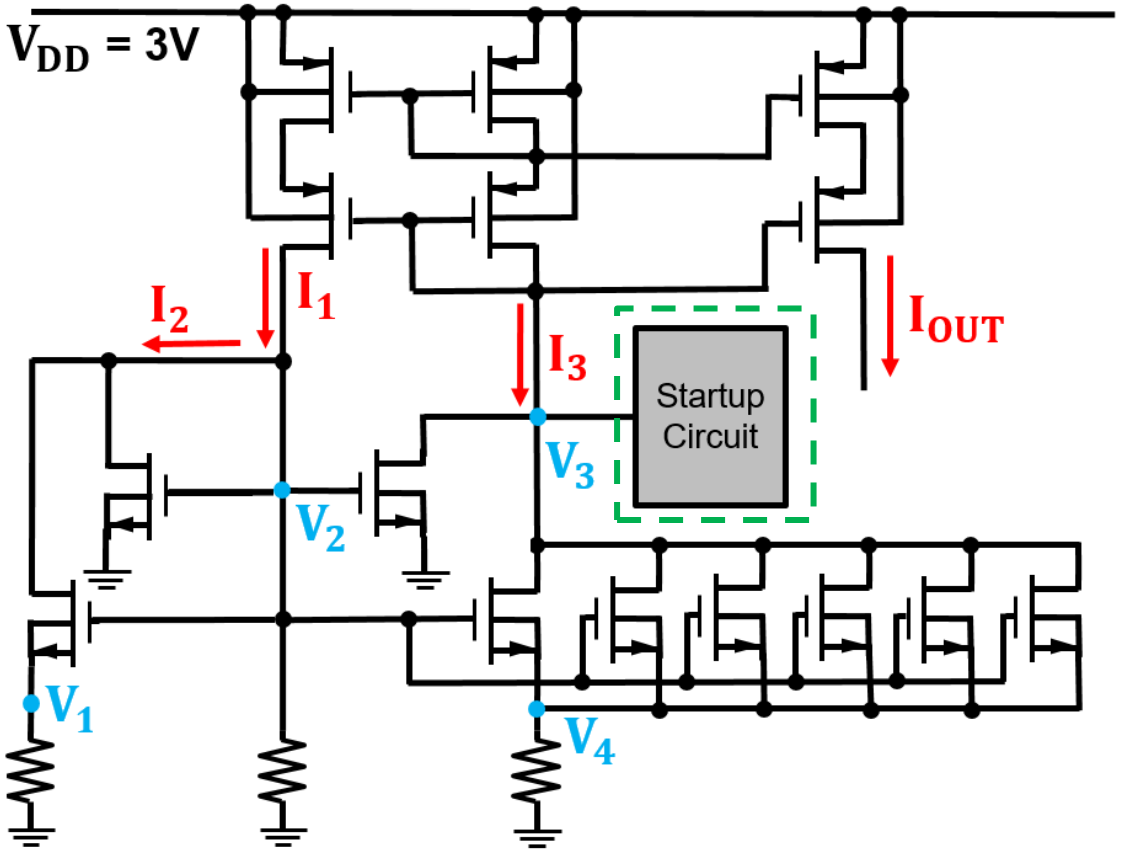
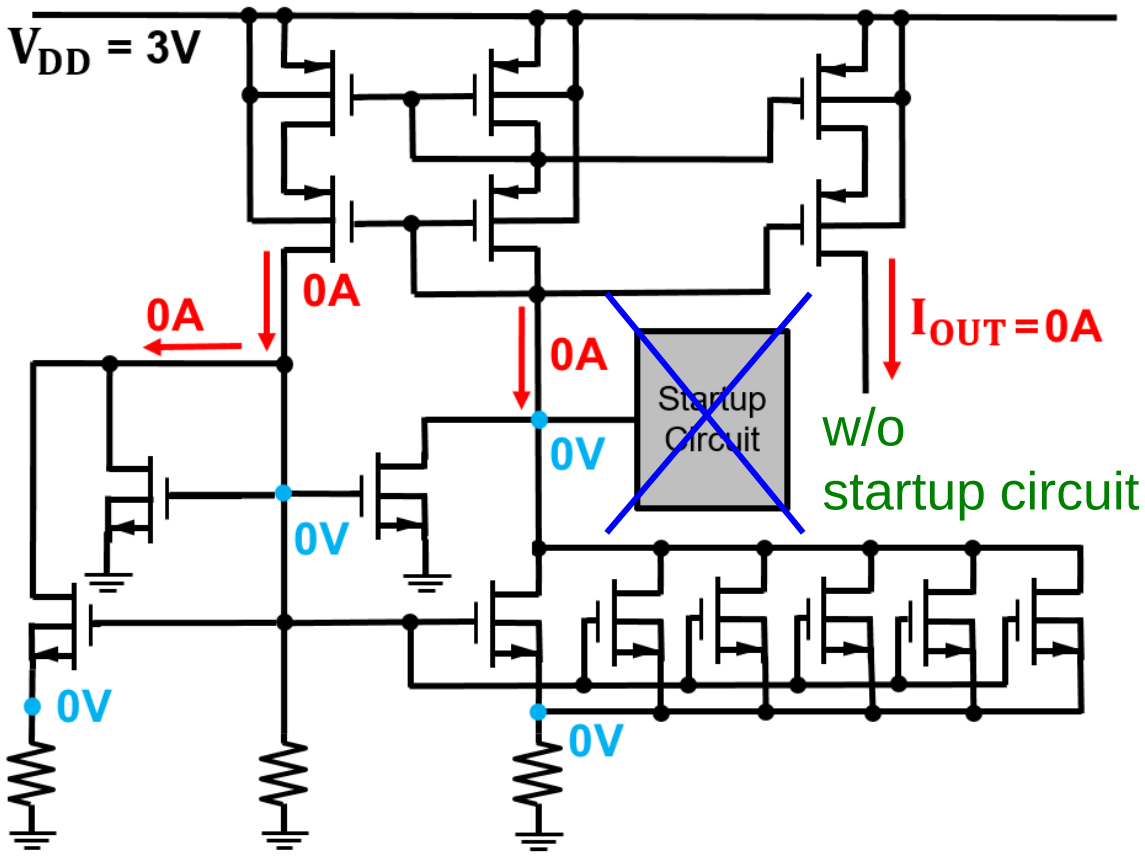
# Need for Startup Circuits




$I_{OUT}$ conduction state

Proper operation




$I_{OUT} = 0$

Malfunction

Compared Three Types of Startup Circuit in terms of Chip area, Power consumption, and Startup operation certainty.

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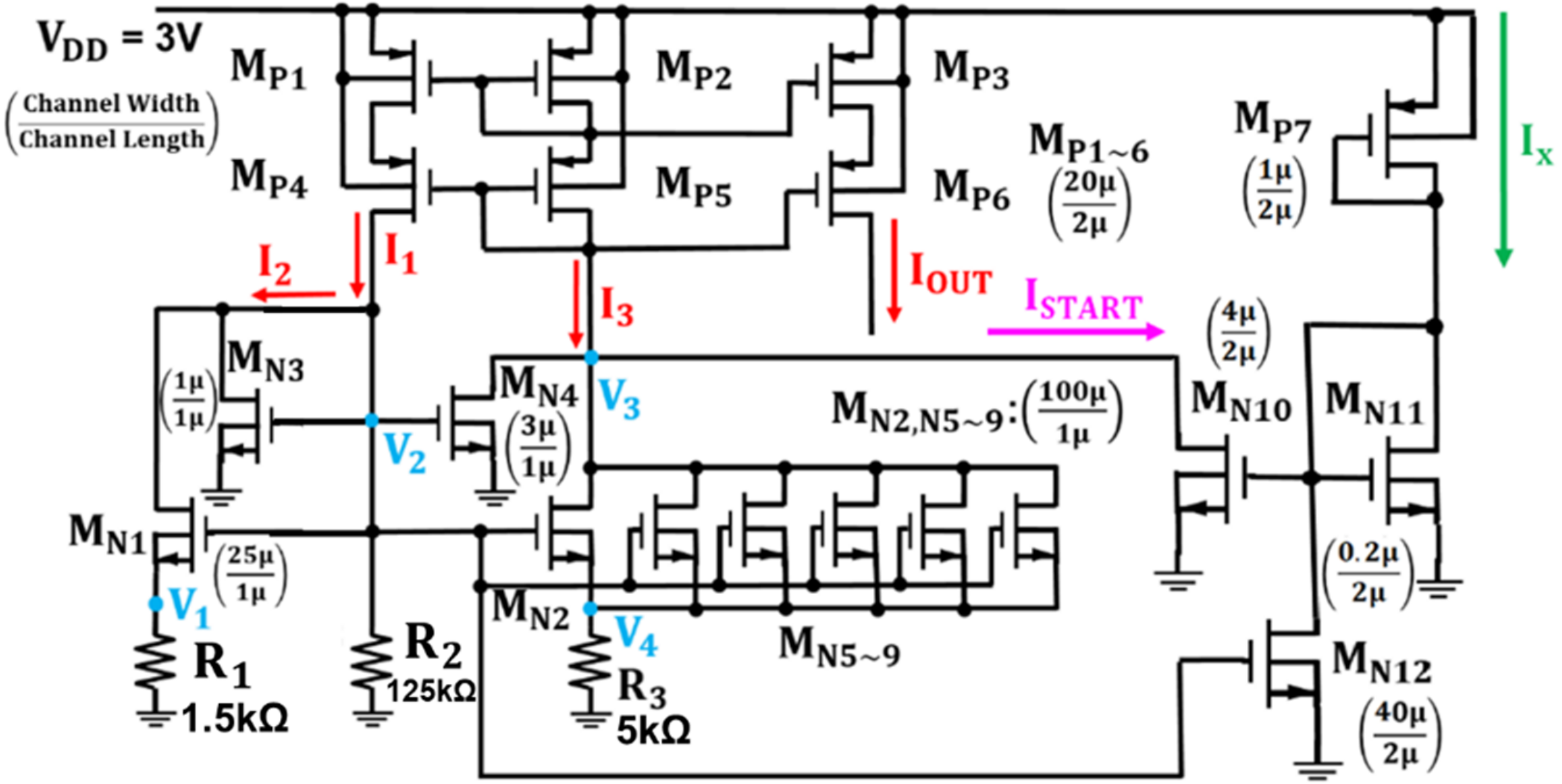
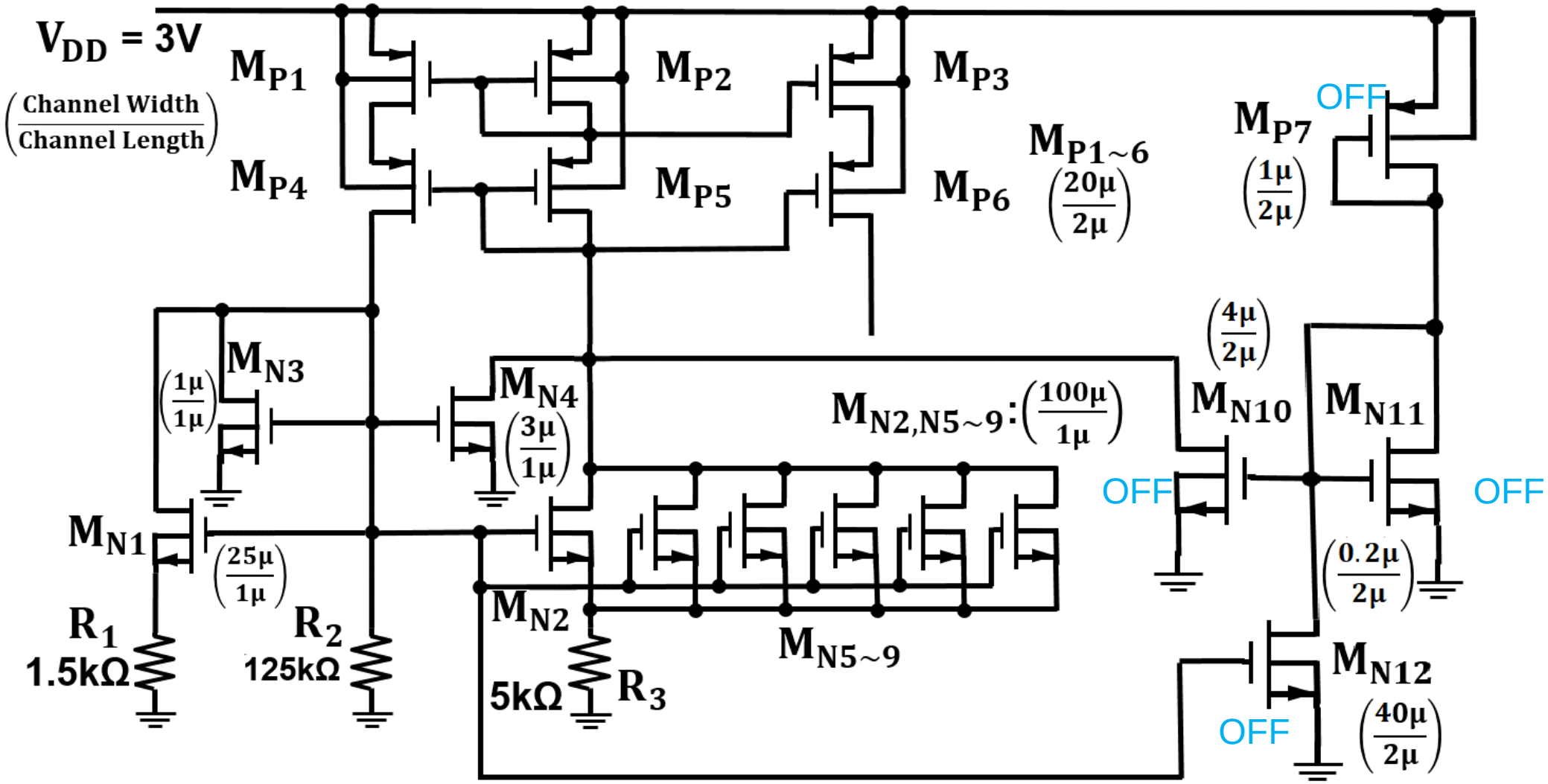
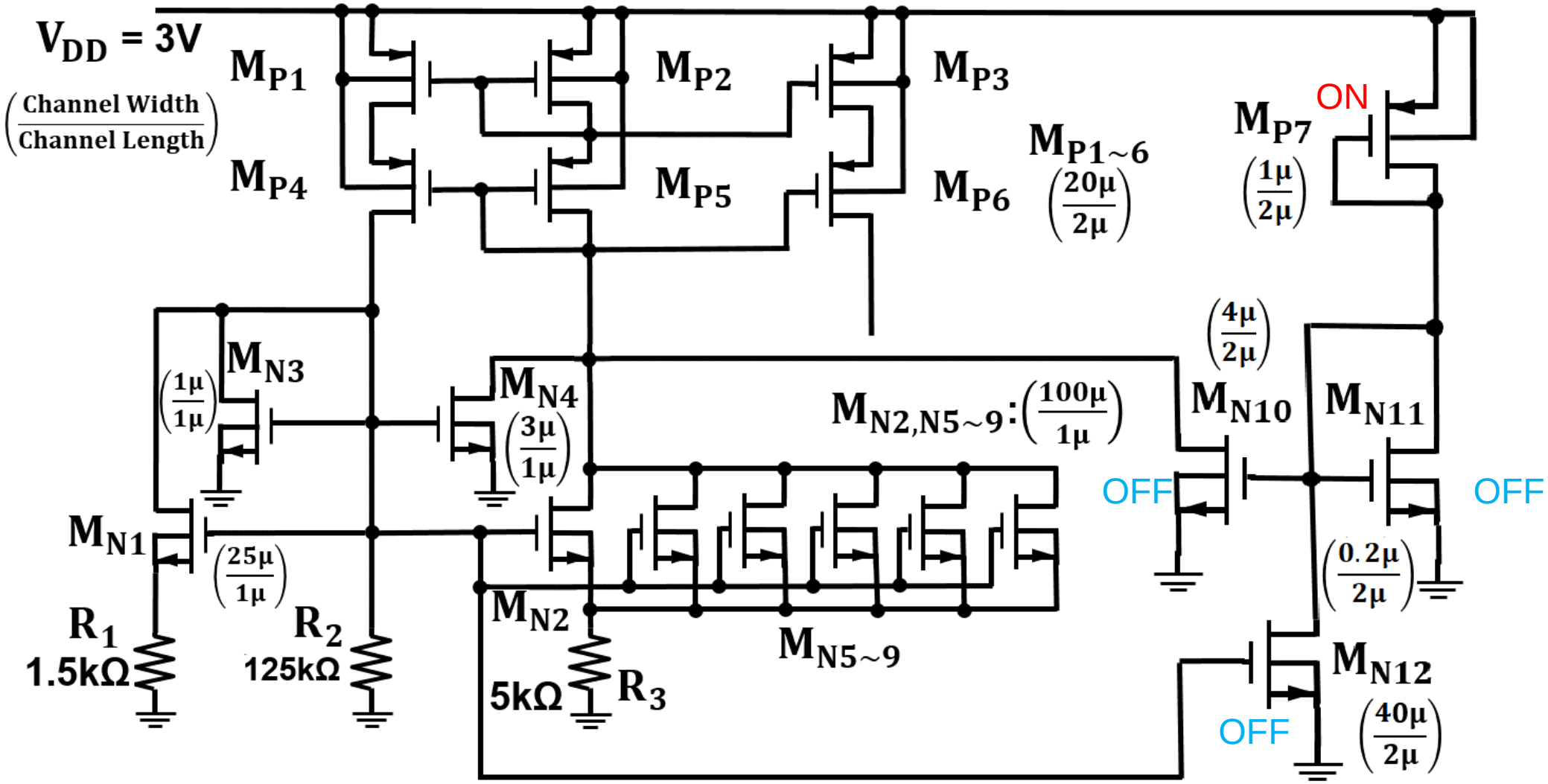
# Startup Circuit 1



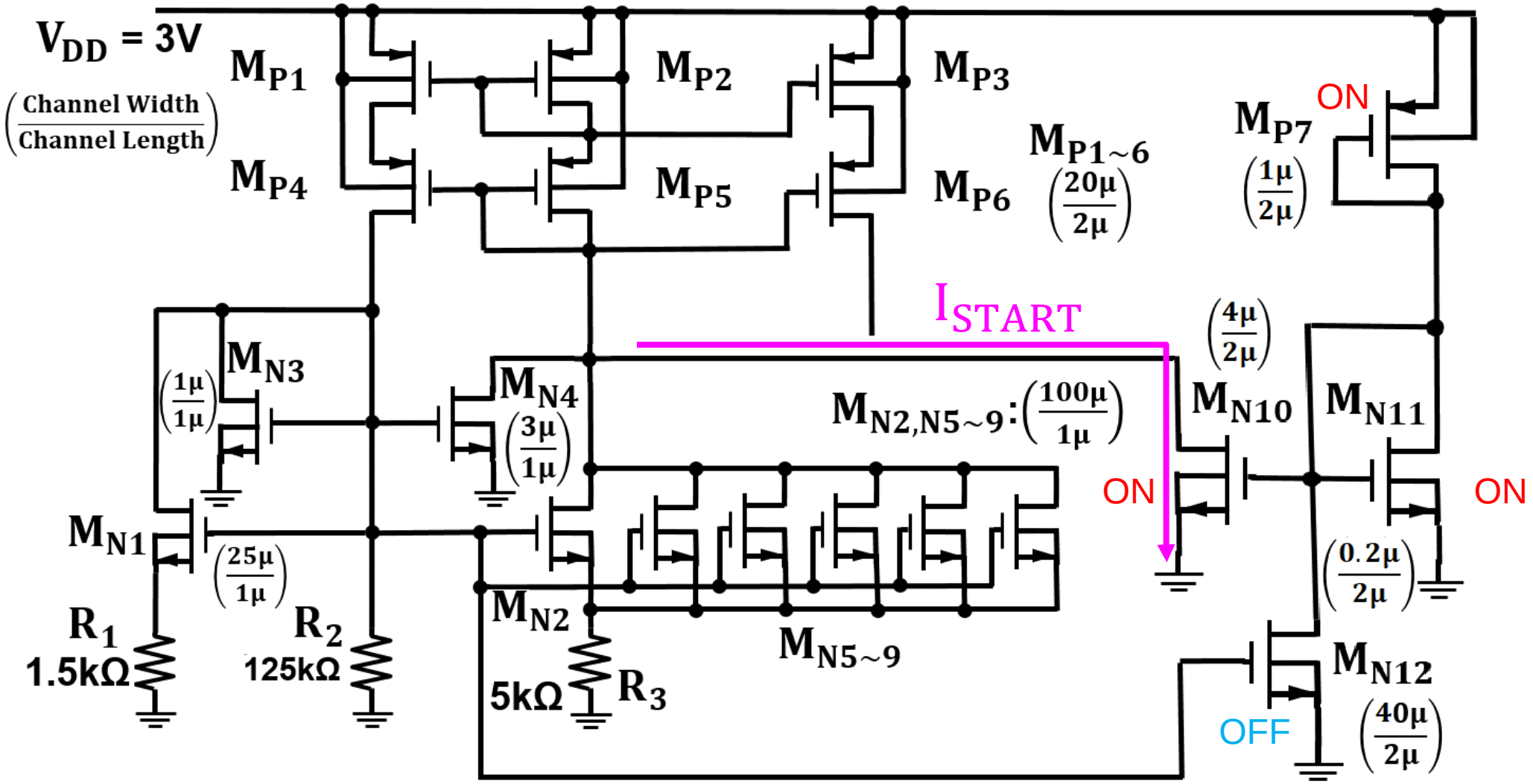
# Operation of Startup Circuit 1 (All node 0V)



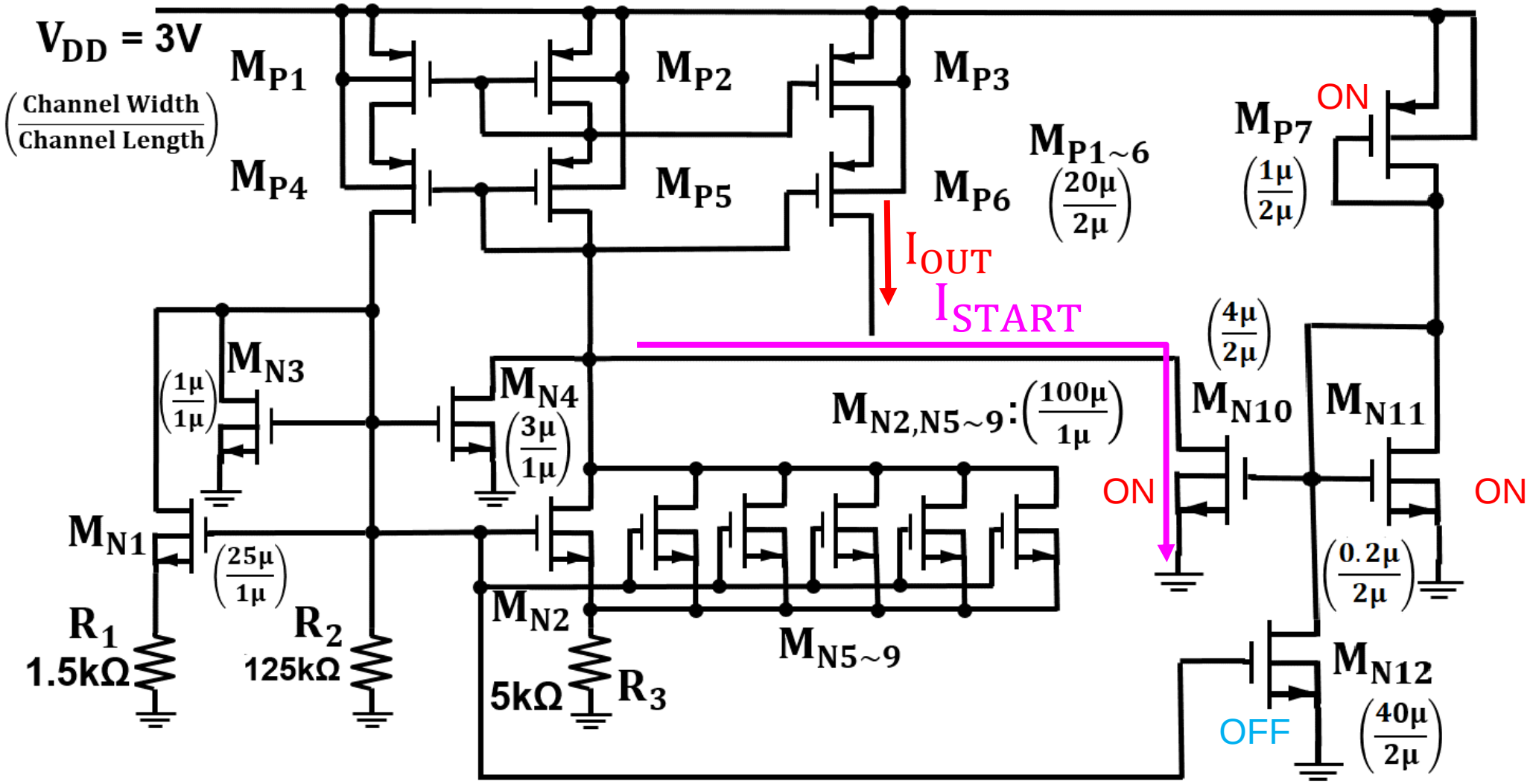
# Operation of Startup Circuit 1 ($M_{P7}$ ON)



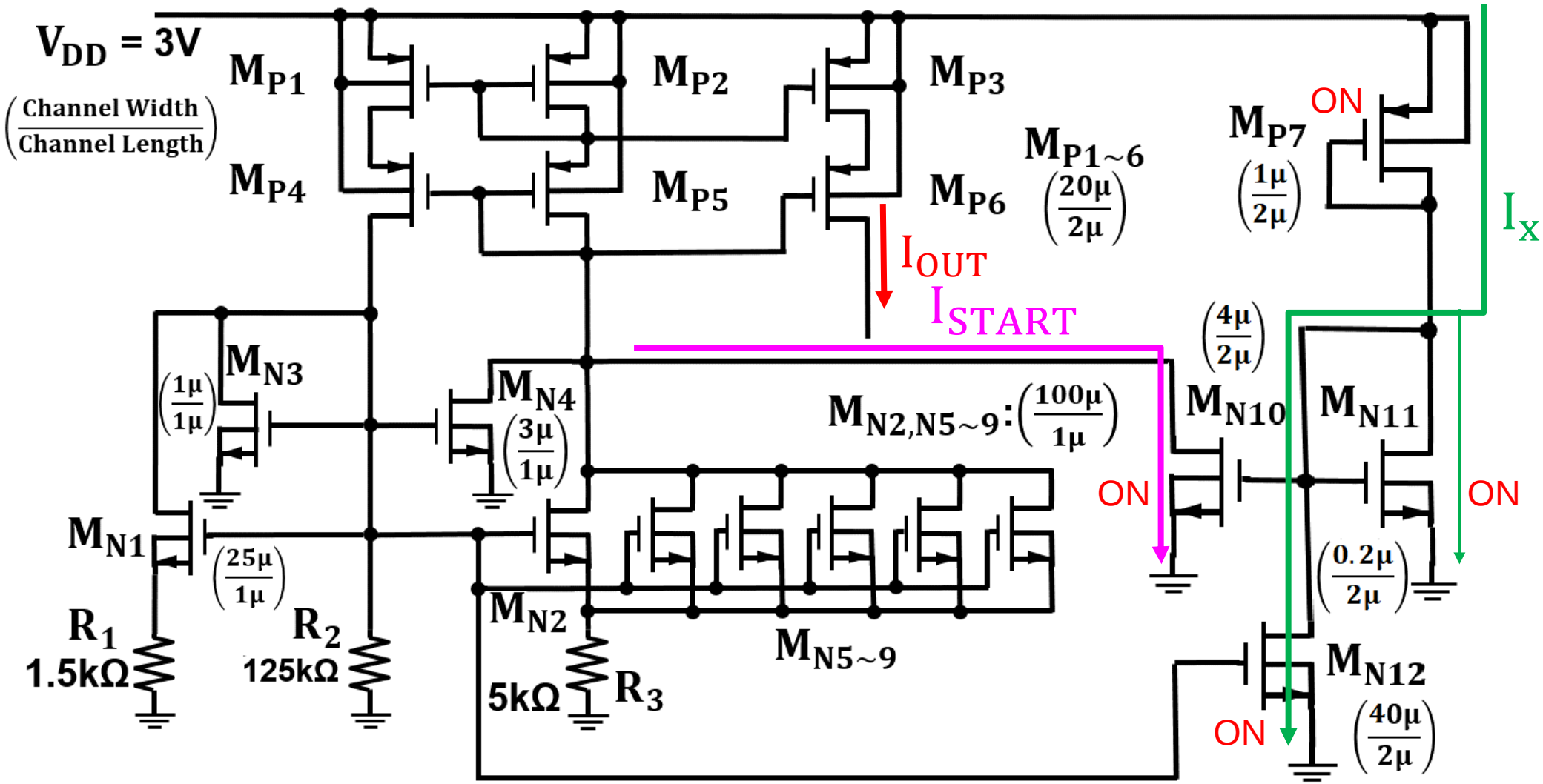
# Operation of Startup Circuit 1 ($M_{N10}$ ON)



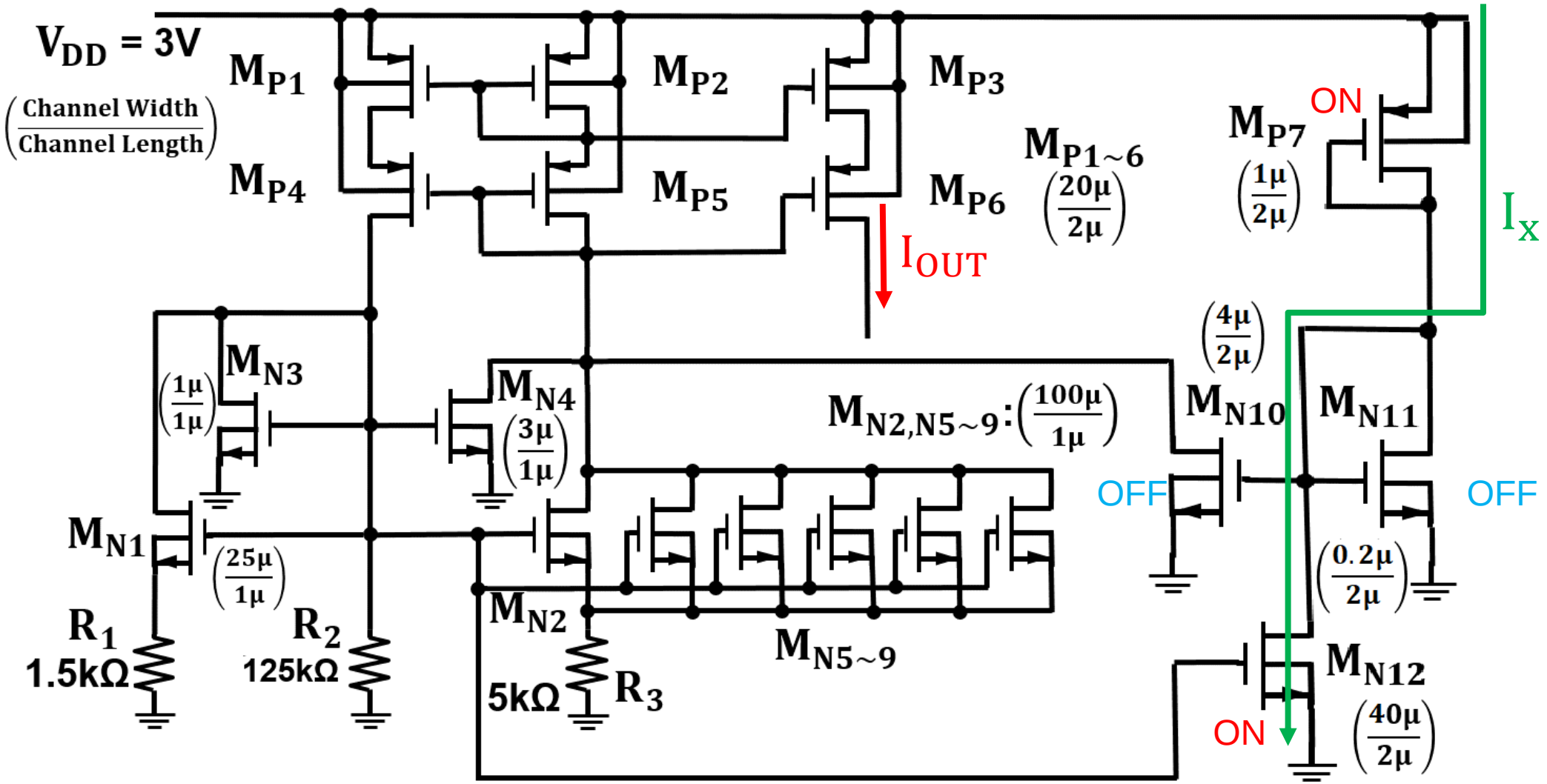
# Operation of Startup Circuit 1 ($I_{OUT}$ flow)



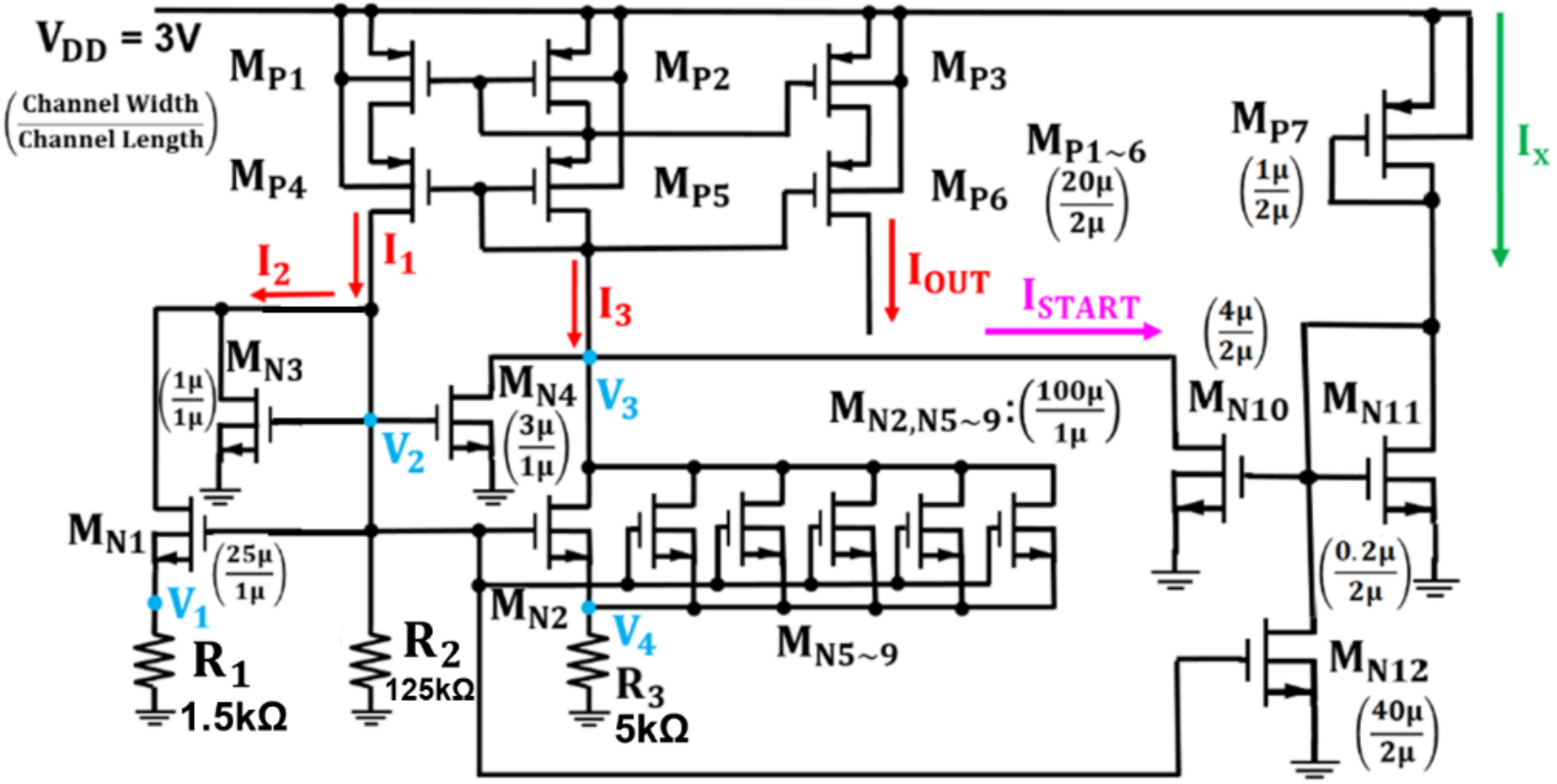
# Operation of Startup Circuit 1 ($M_{N12}$ ON)

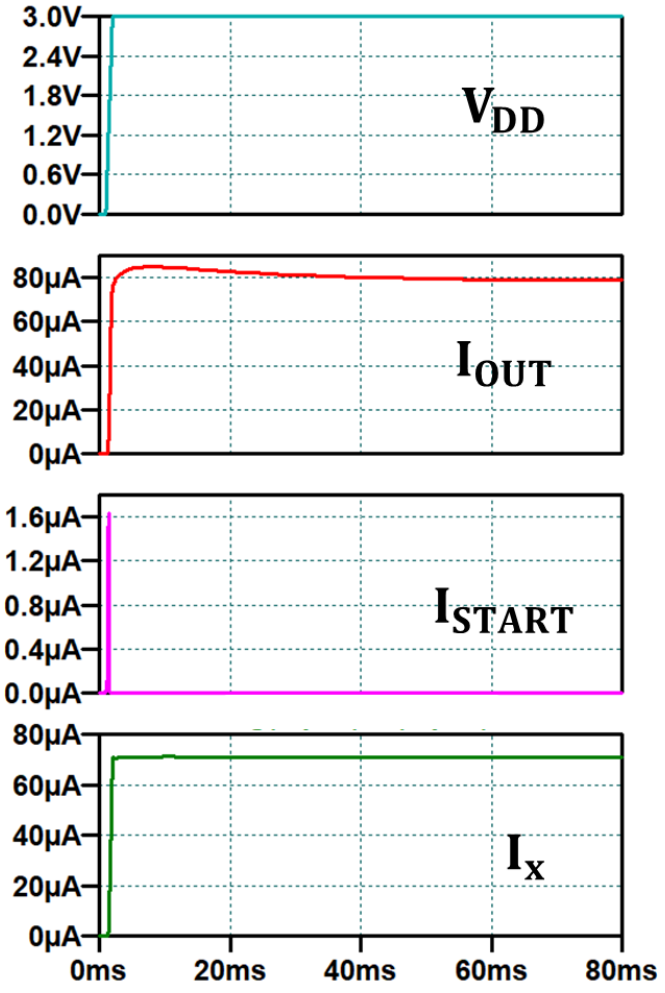


# Operation of Startup Circuit 1 ($M_{N10}$ OFF)



# Demerit of Startup Circuit 1




**Demerit**😭

- Large power consumption

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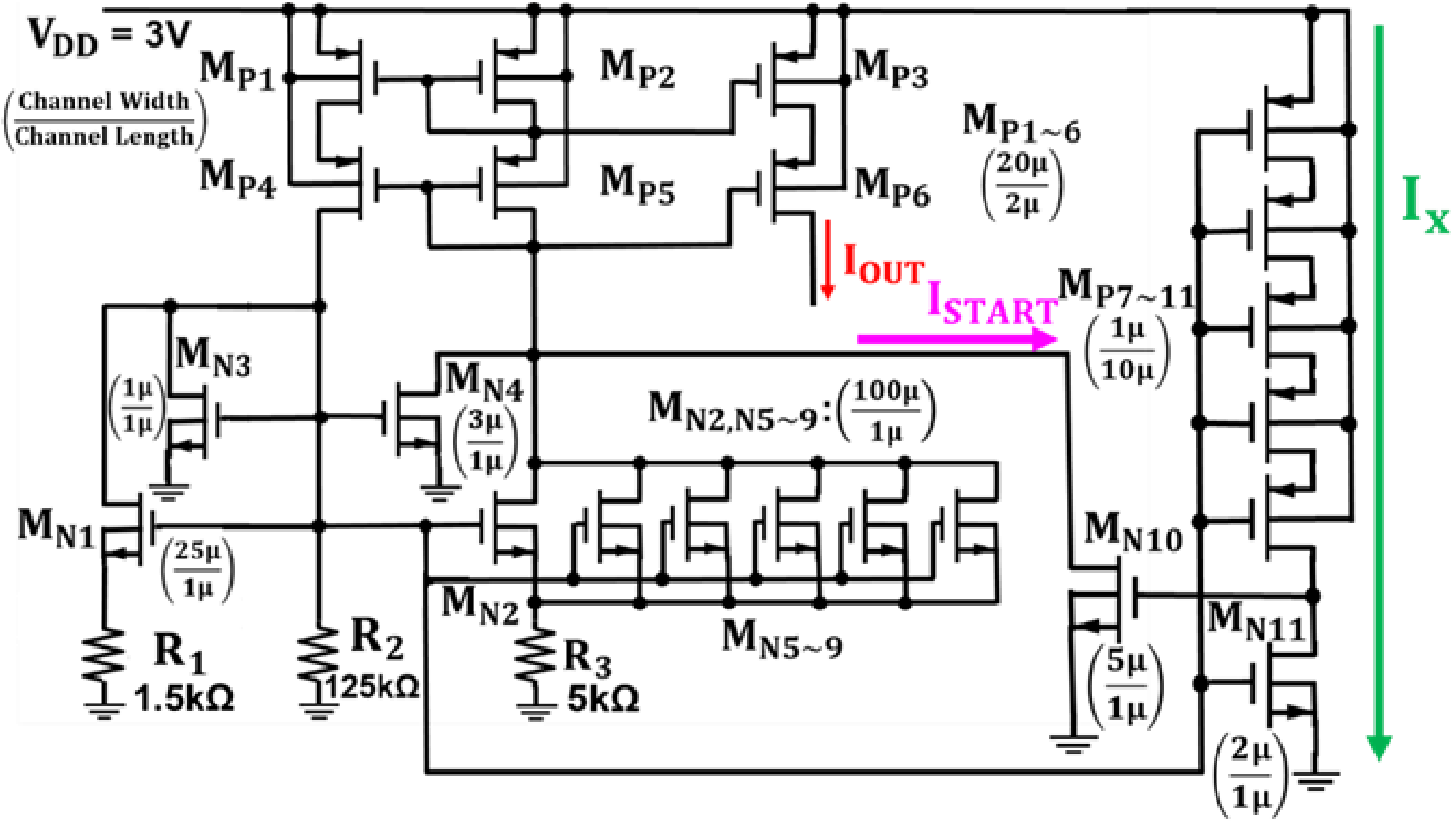
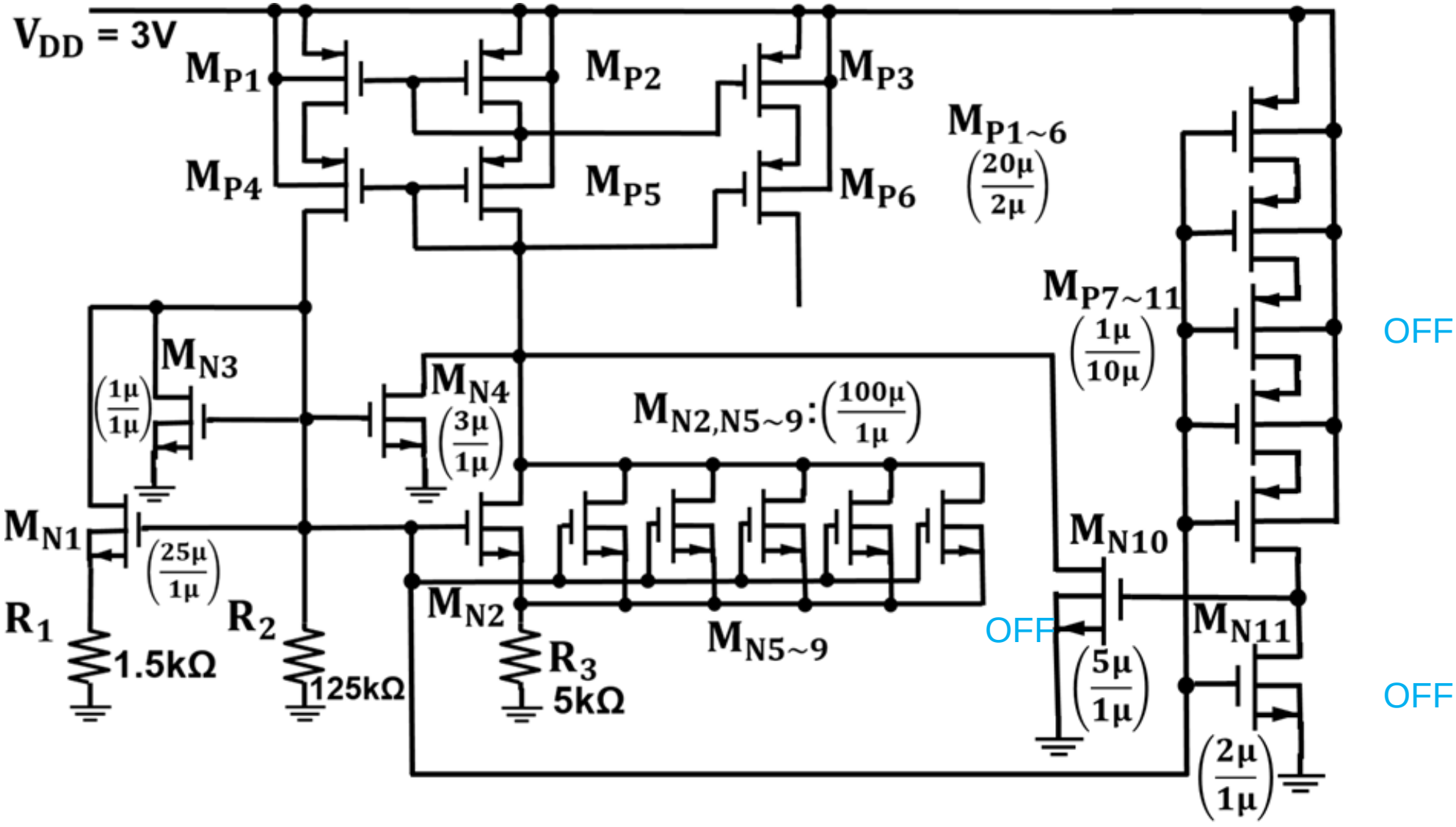
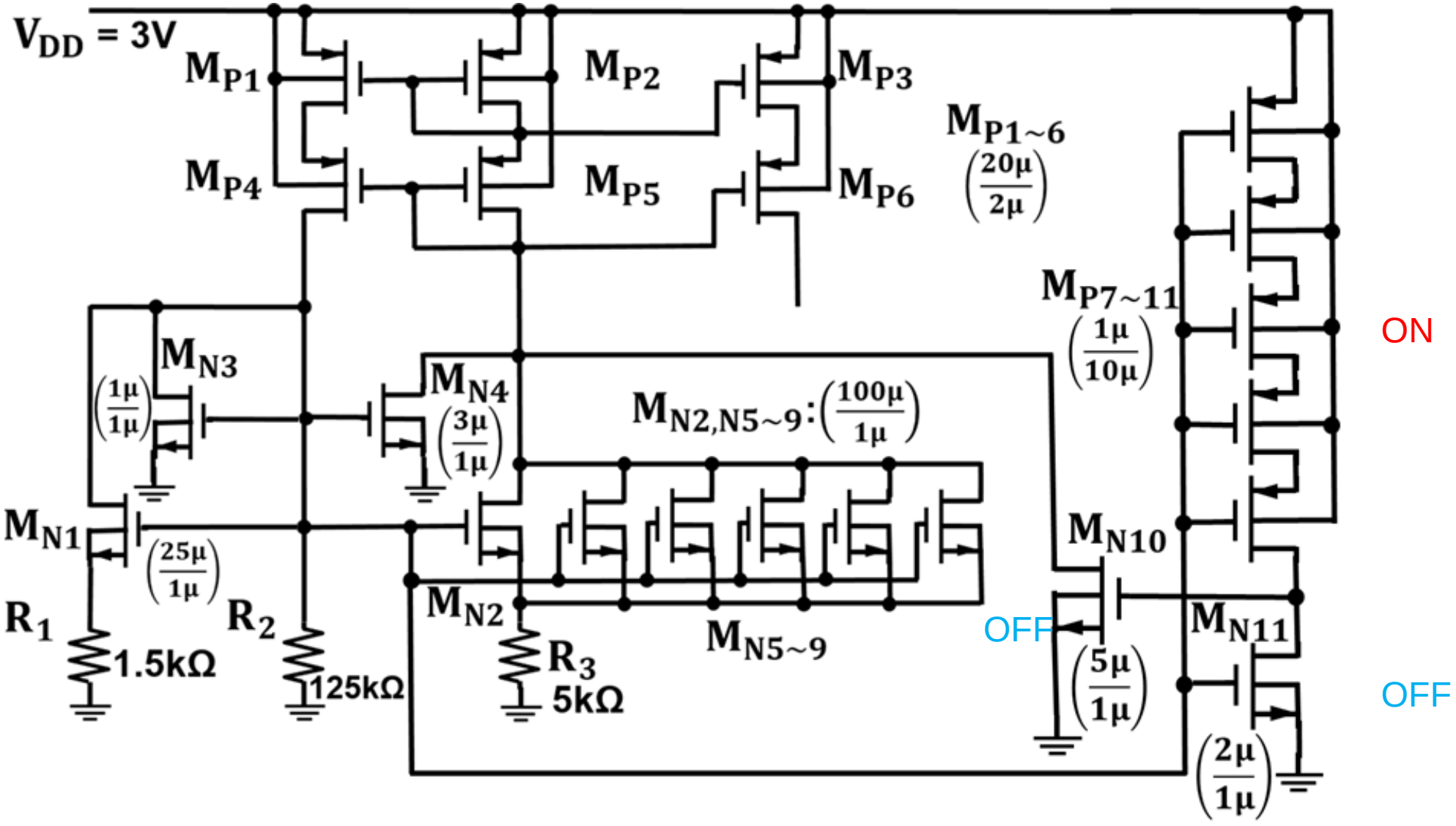
# Startup Circuit 2 (CMOS inverter usage)



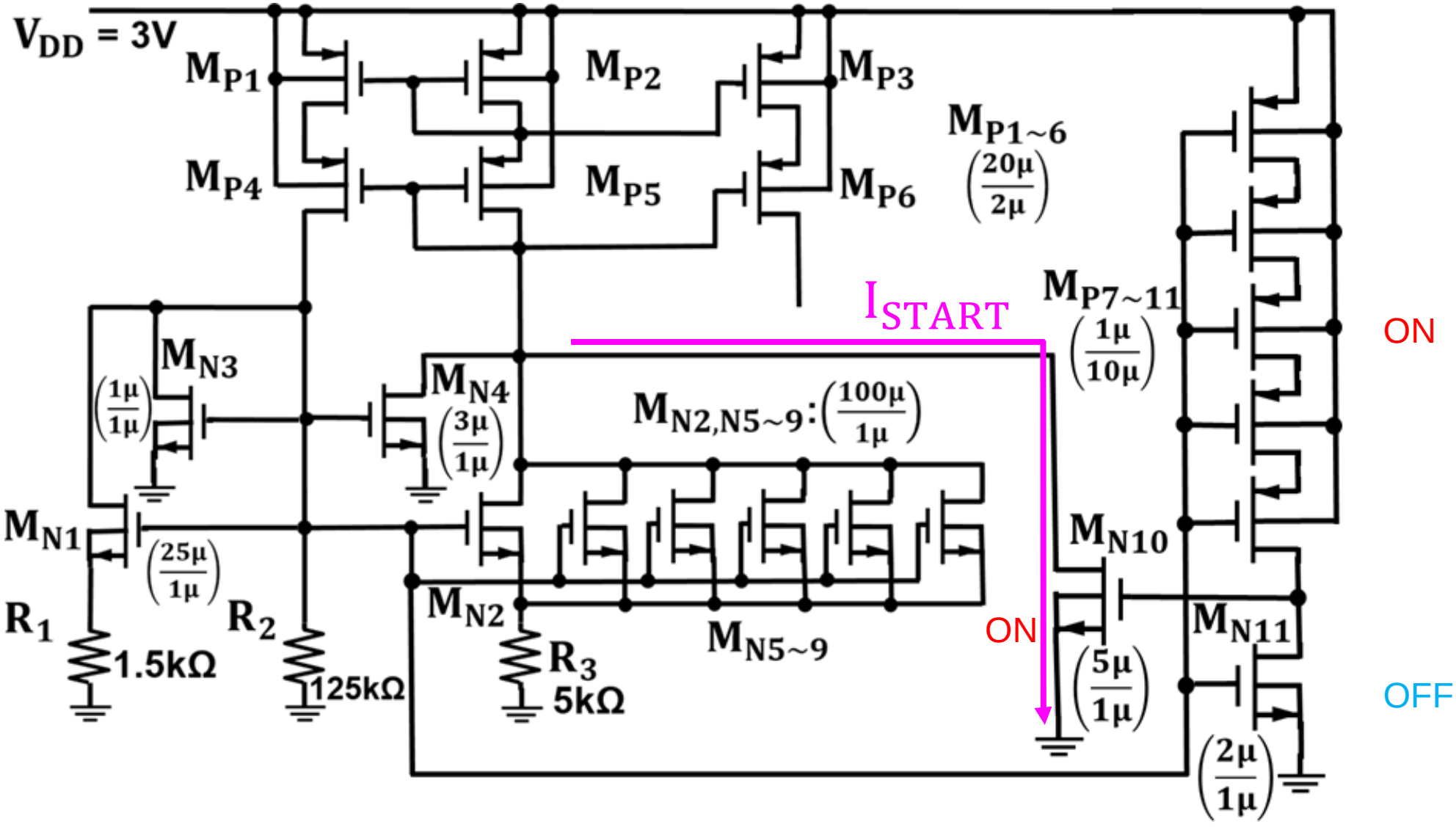
# Operation of Startup Circuit 2 (All node 0V)



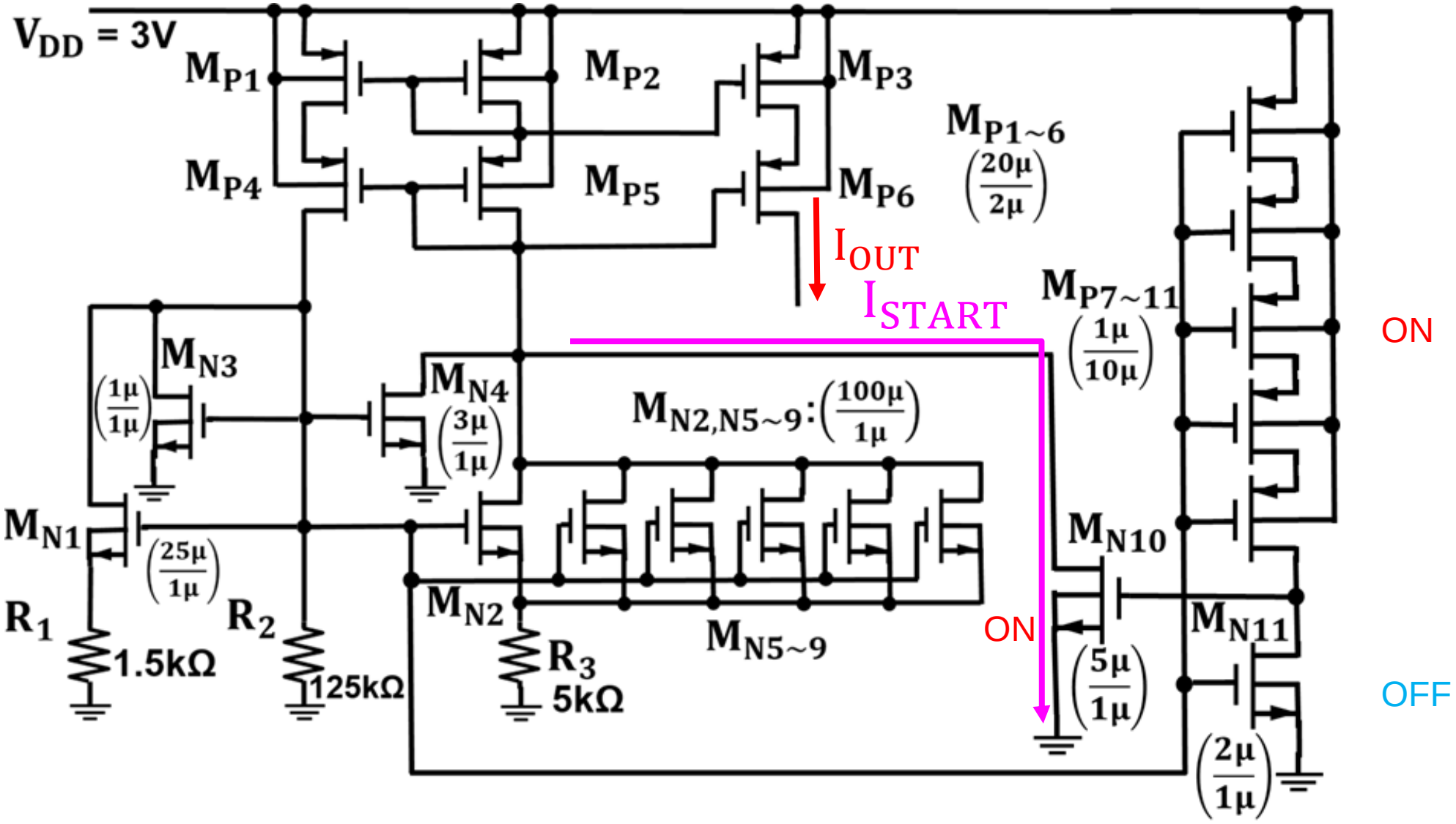
# Operation of Startup Circuit 2 ($M_{P7\sim11}$ ON)



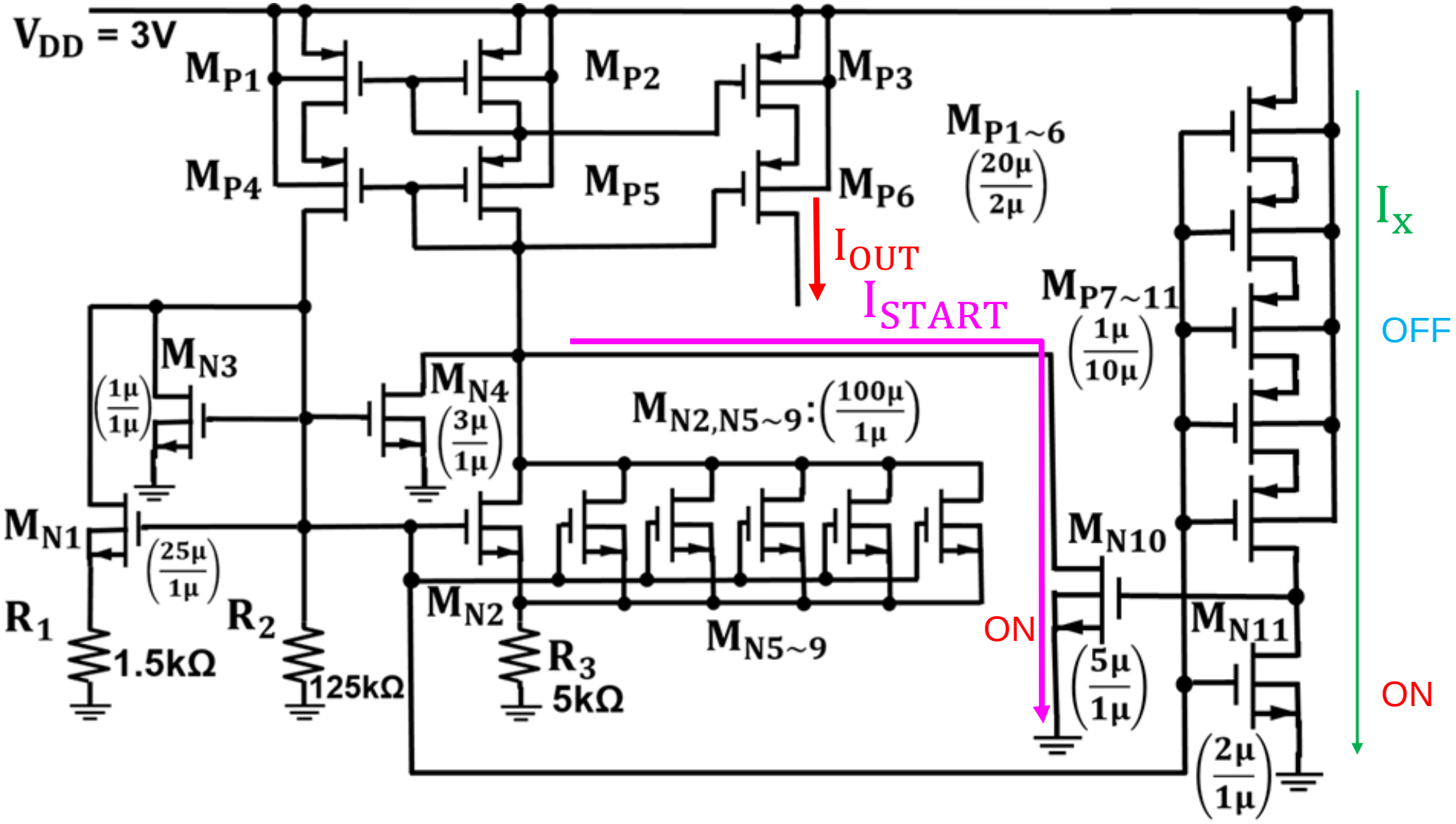
# Operation of Startup Circuit 2 ($M_{N10}$ ON)



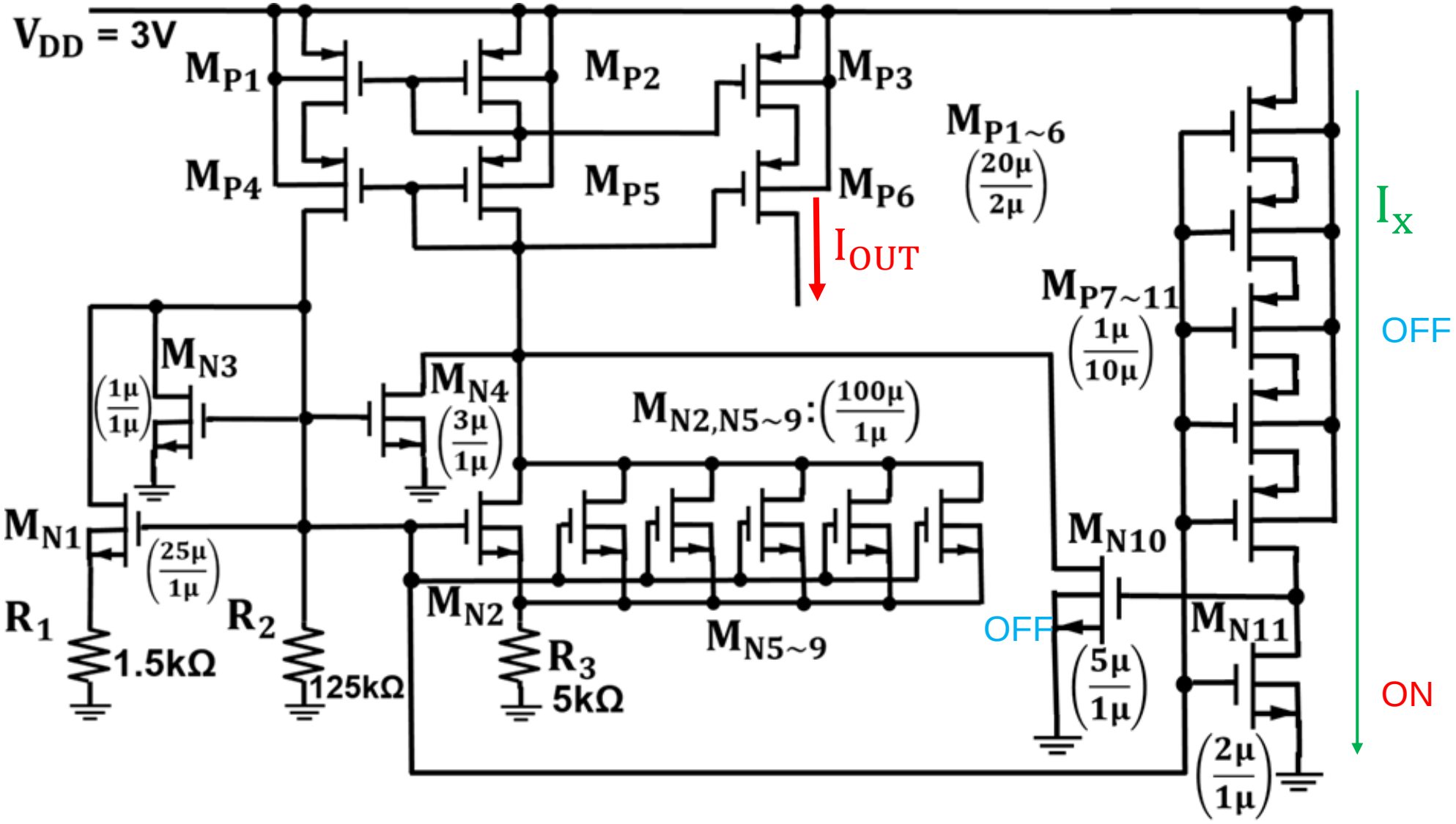
# Operation of Startup Circuit 2 ($I_{OUT}$ flow)



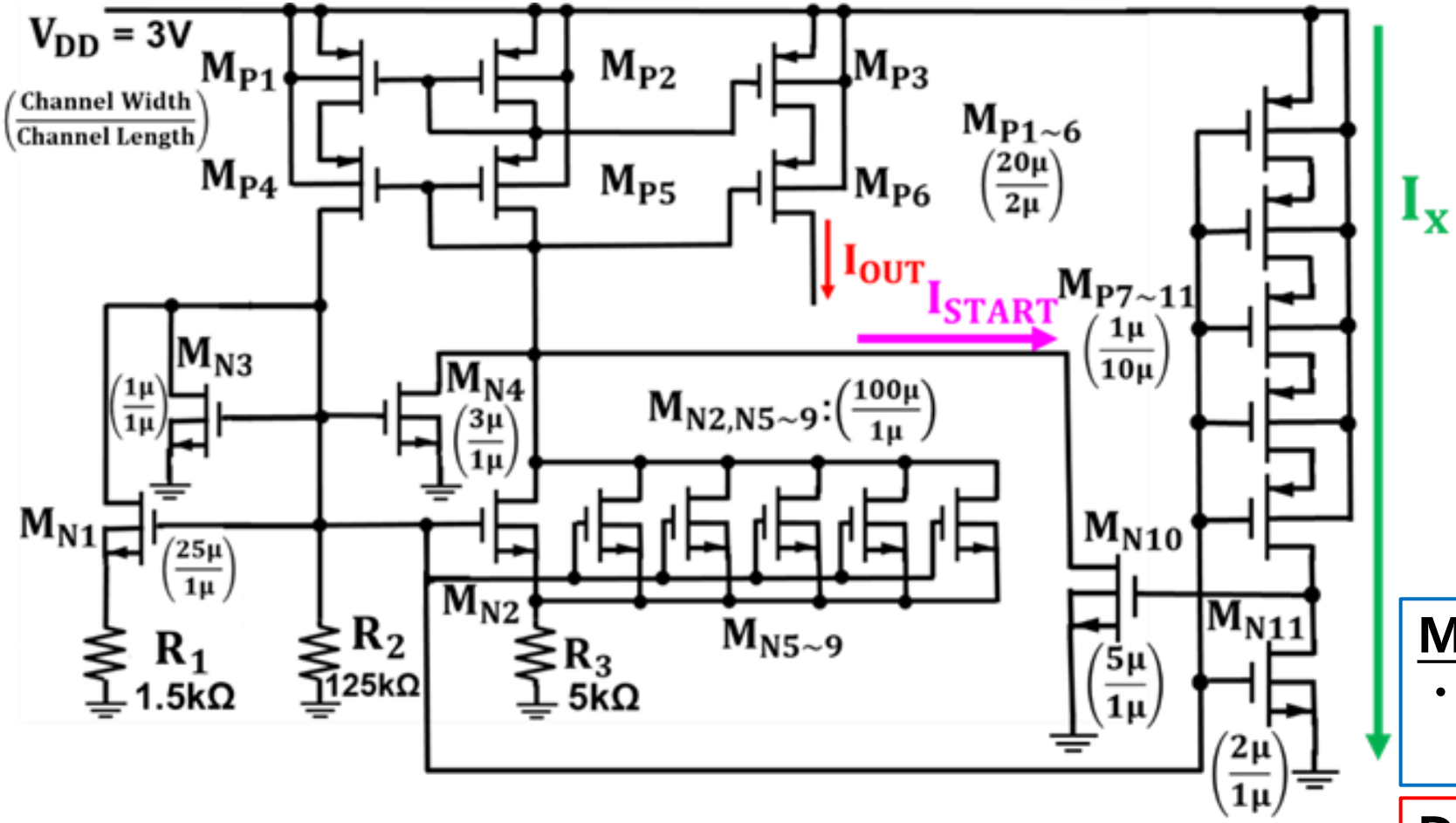
# Operation of Startup Circuit 2 ($M_{P7\sim11}$ OFF, $M_{N11}$ ON)

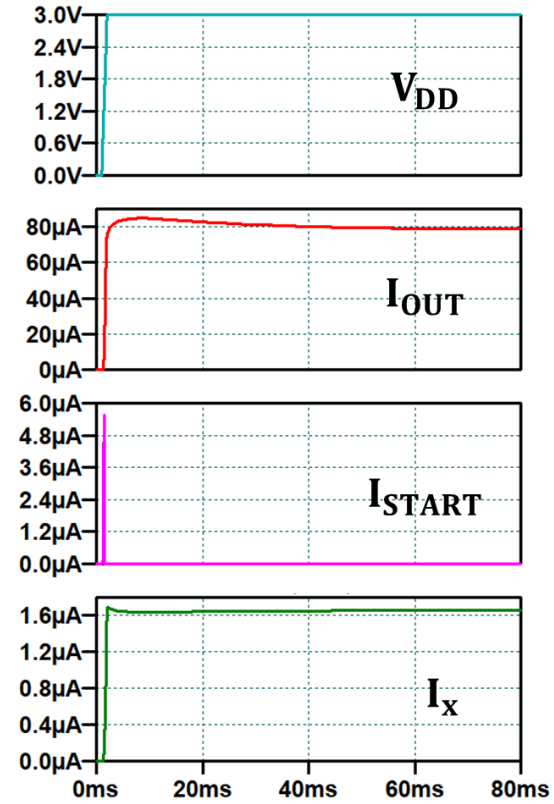


# Operation of Startup Circuit 2 ($M_{N10}$ OFF)



# Merit and Demerit of Startup Circuit 2




**Merit** 😊

- Some reduction in power consumption

**Demerit** 😭

- Some increase in chip area

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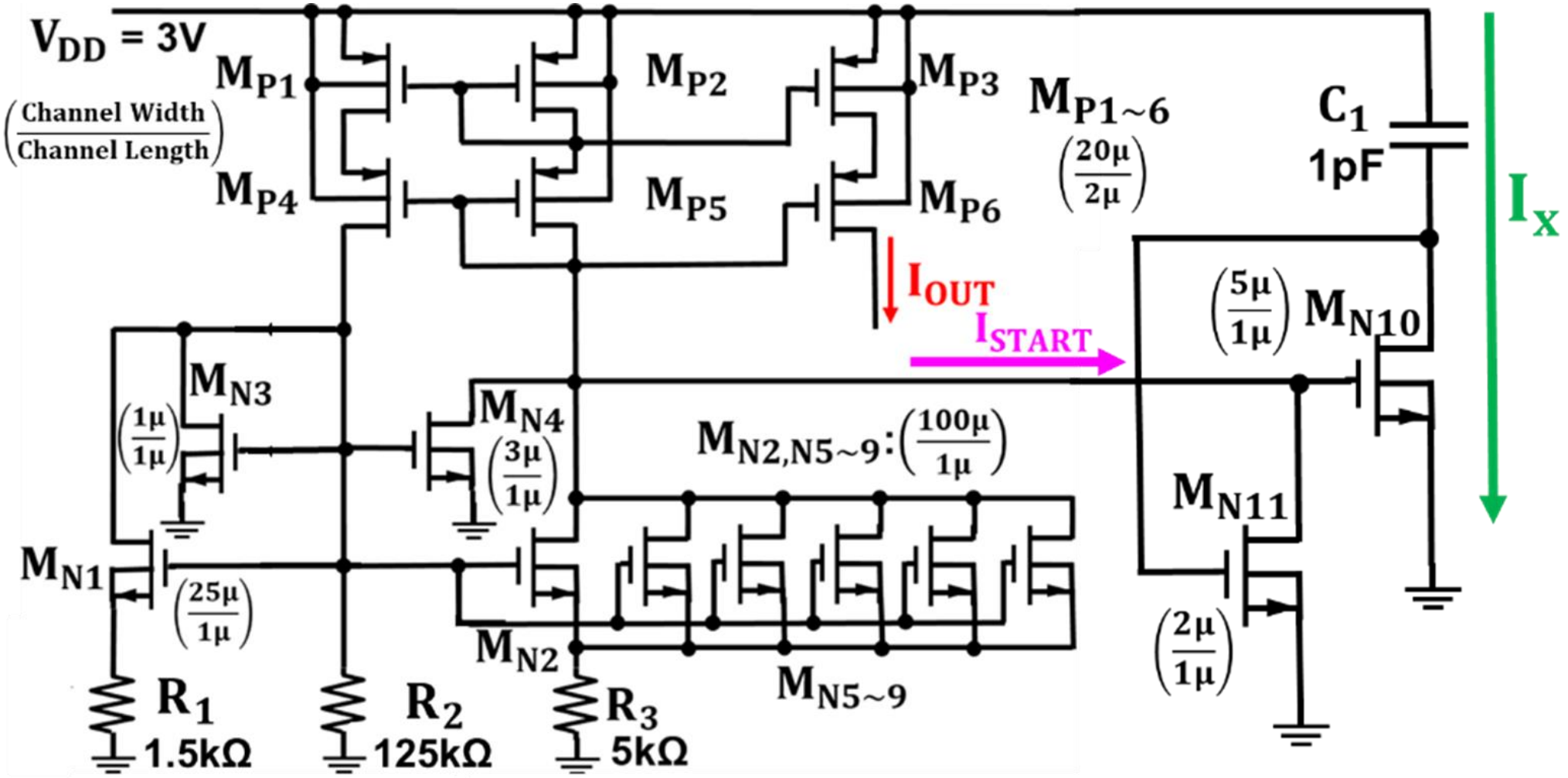
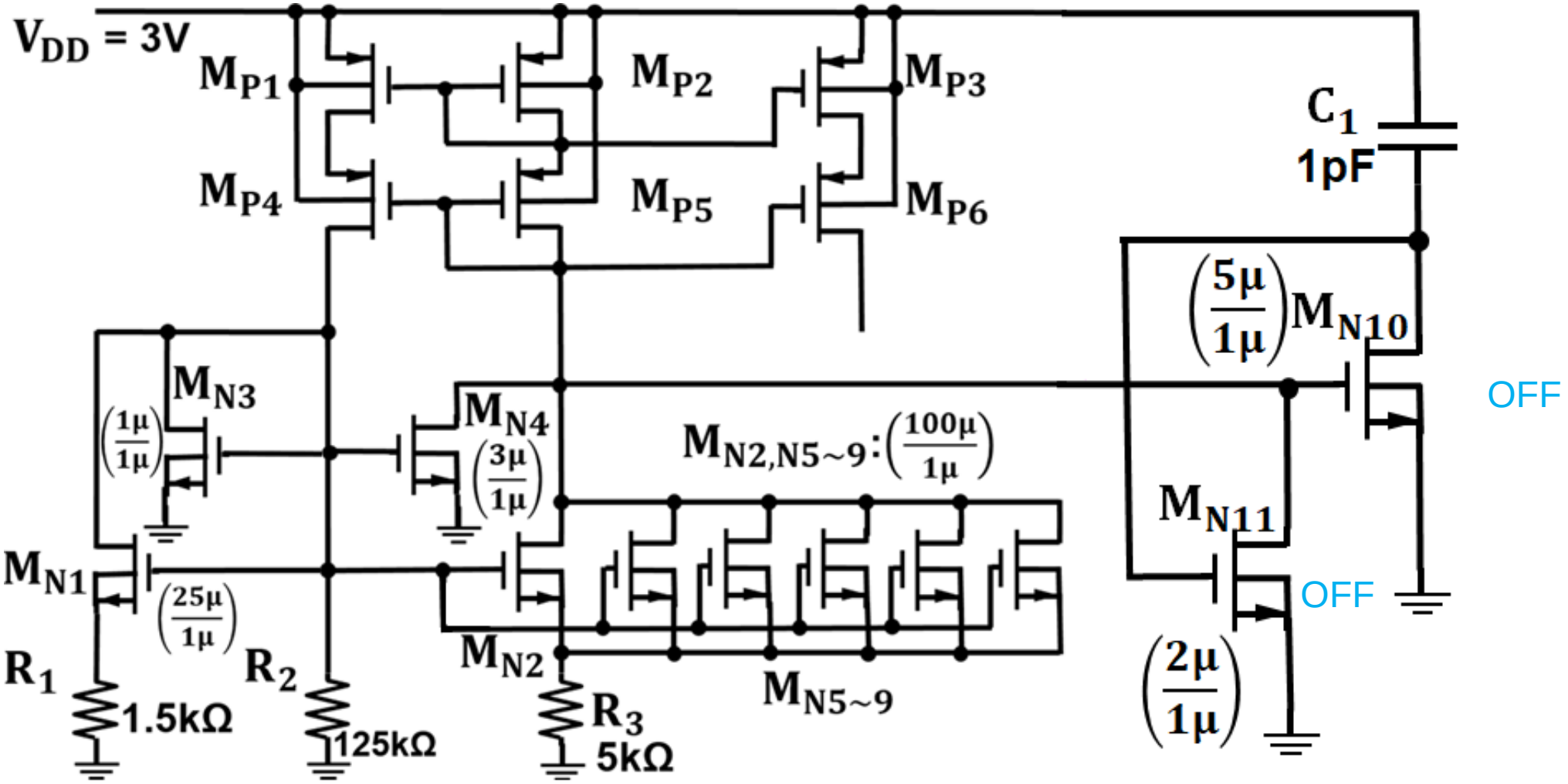
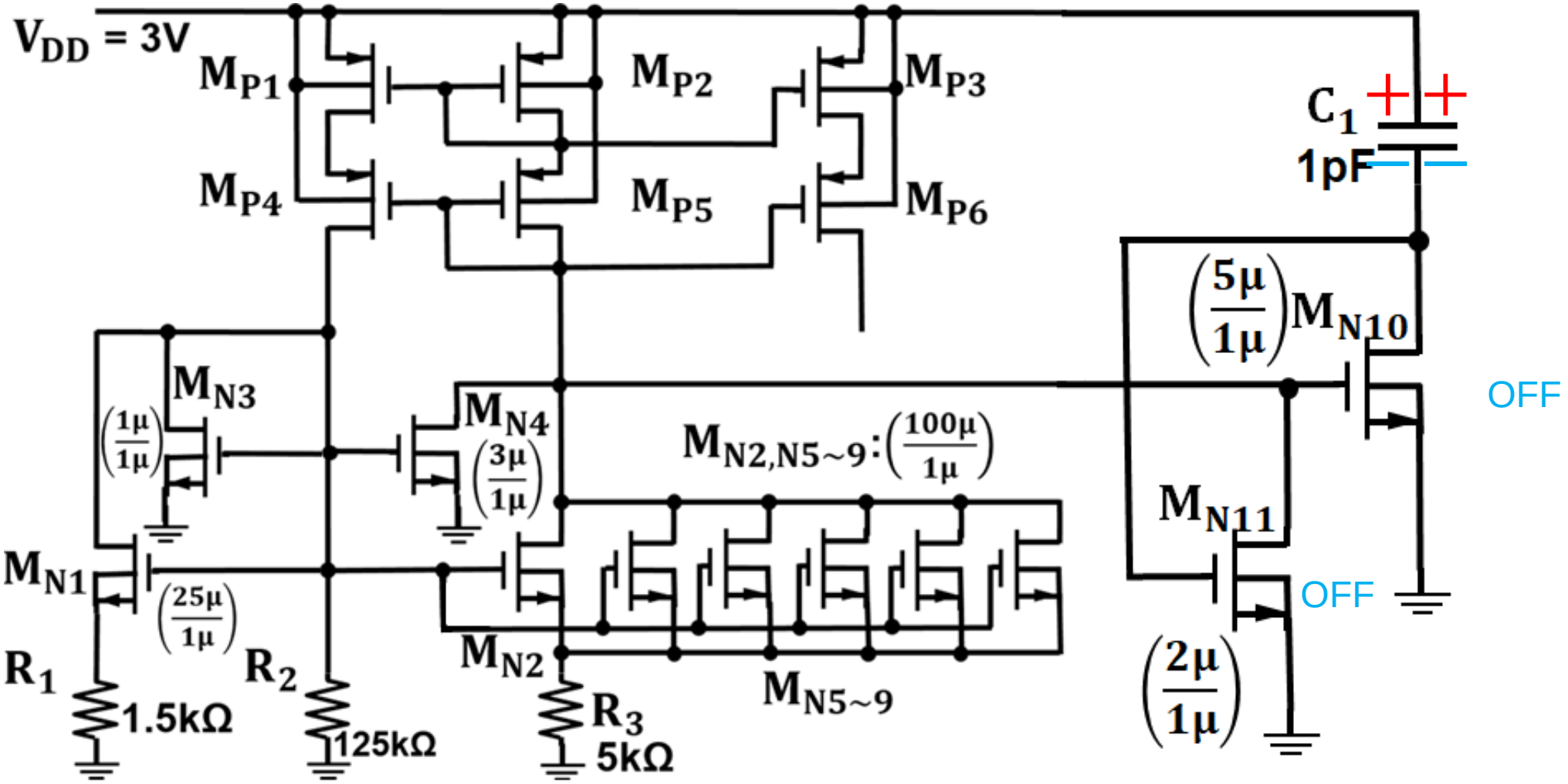
# Startup Circuit 3 (Capacitor usage)



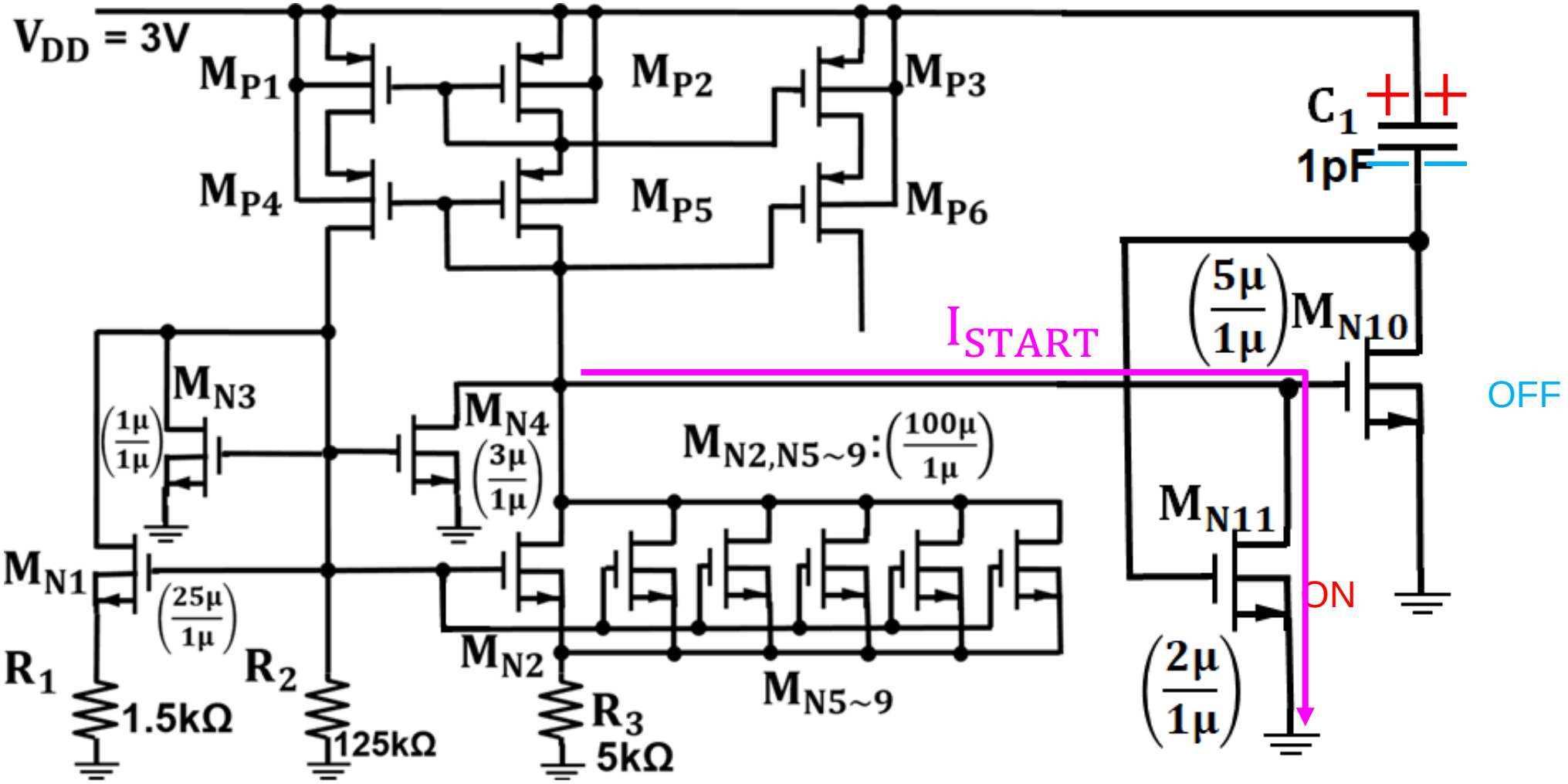
# Operation of Startup Circuit 3 (All node 0V)



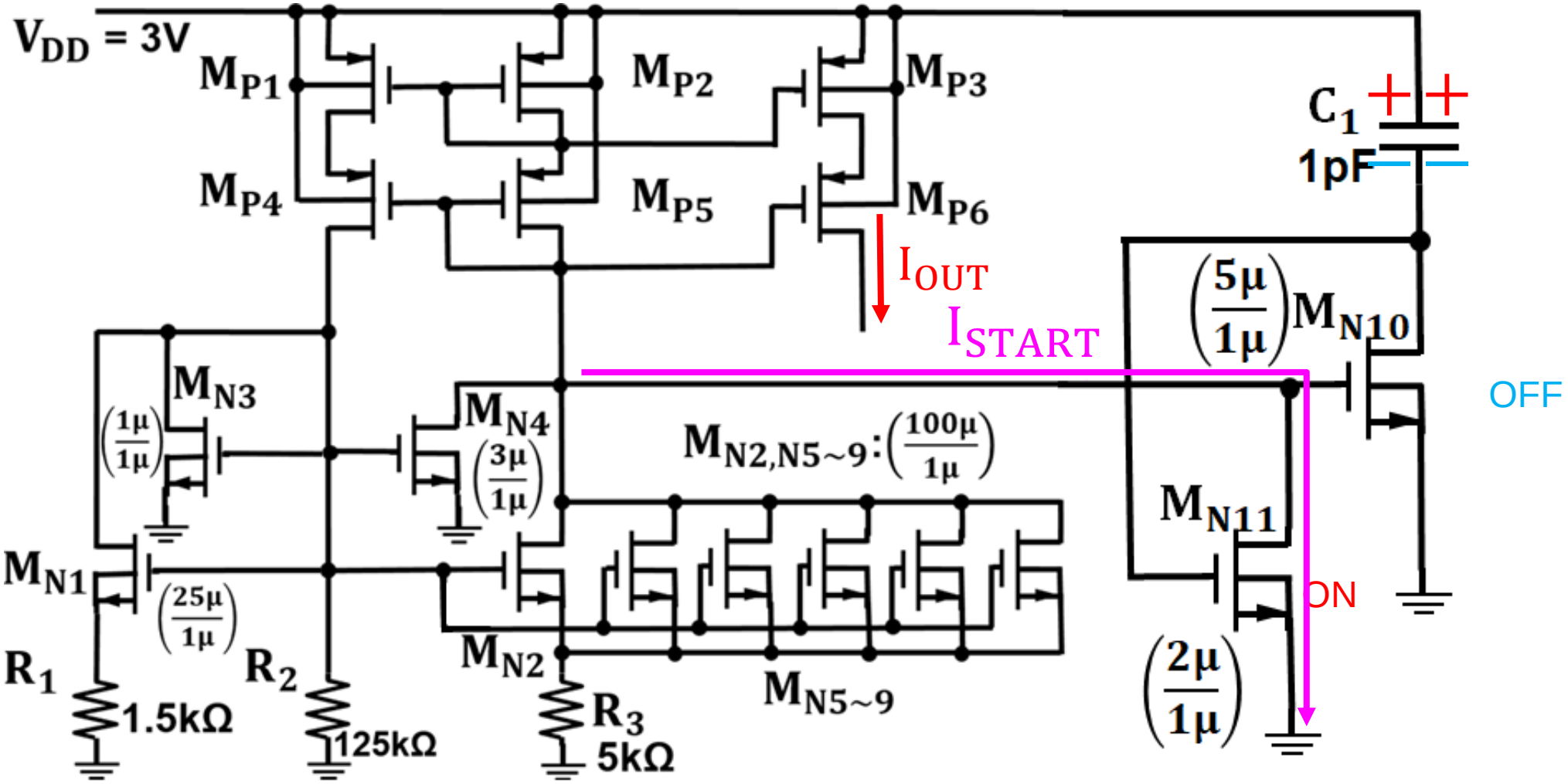
# Operation of Startup Circuit 3 ($C_1$ Charged)



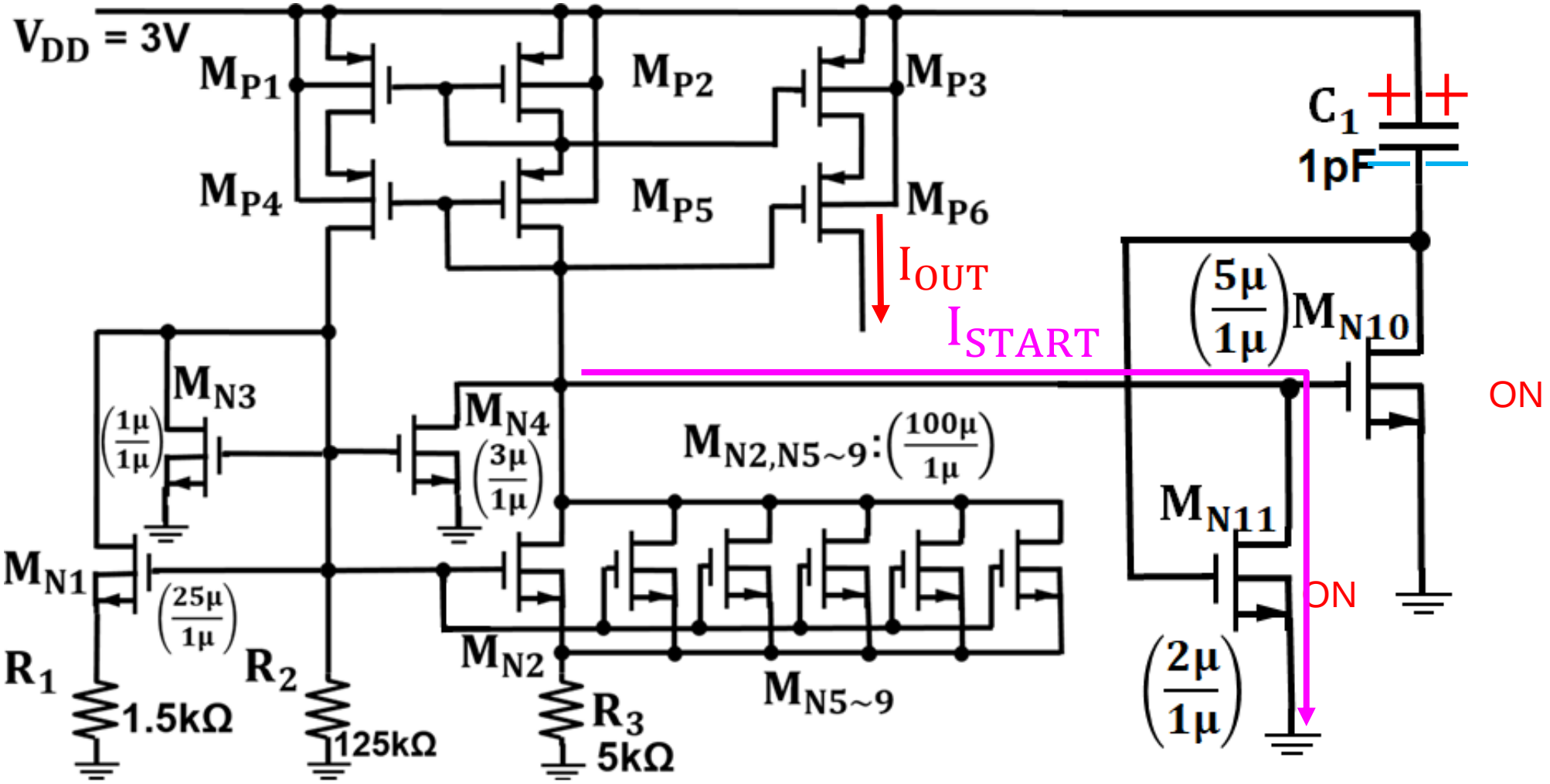
# Operation of Startup Circuit 3 ($M_{N11}$ ON)



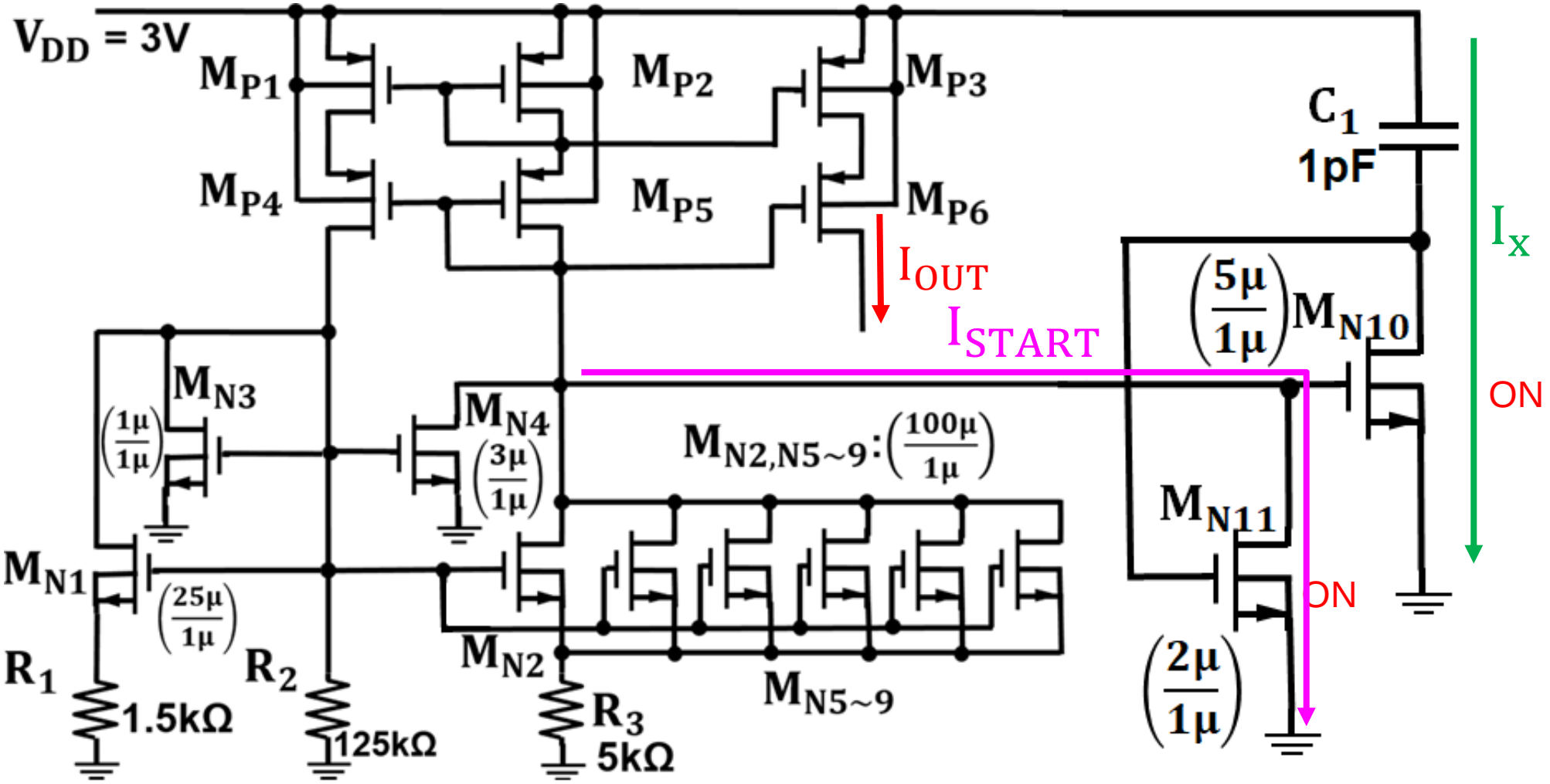
# Operation of Startup Circuit 3 ($I_{OUT}$ flow)



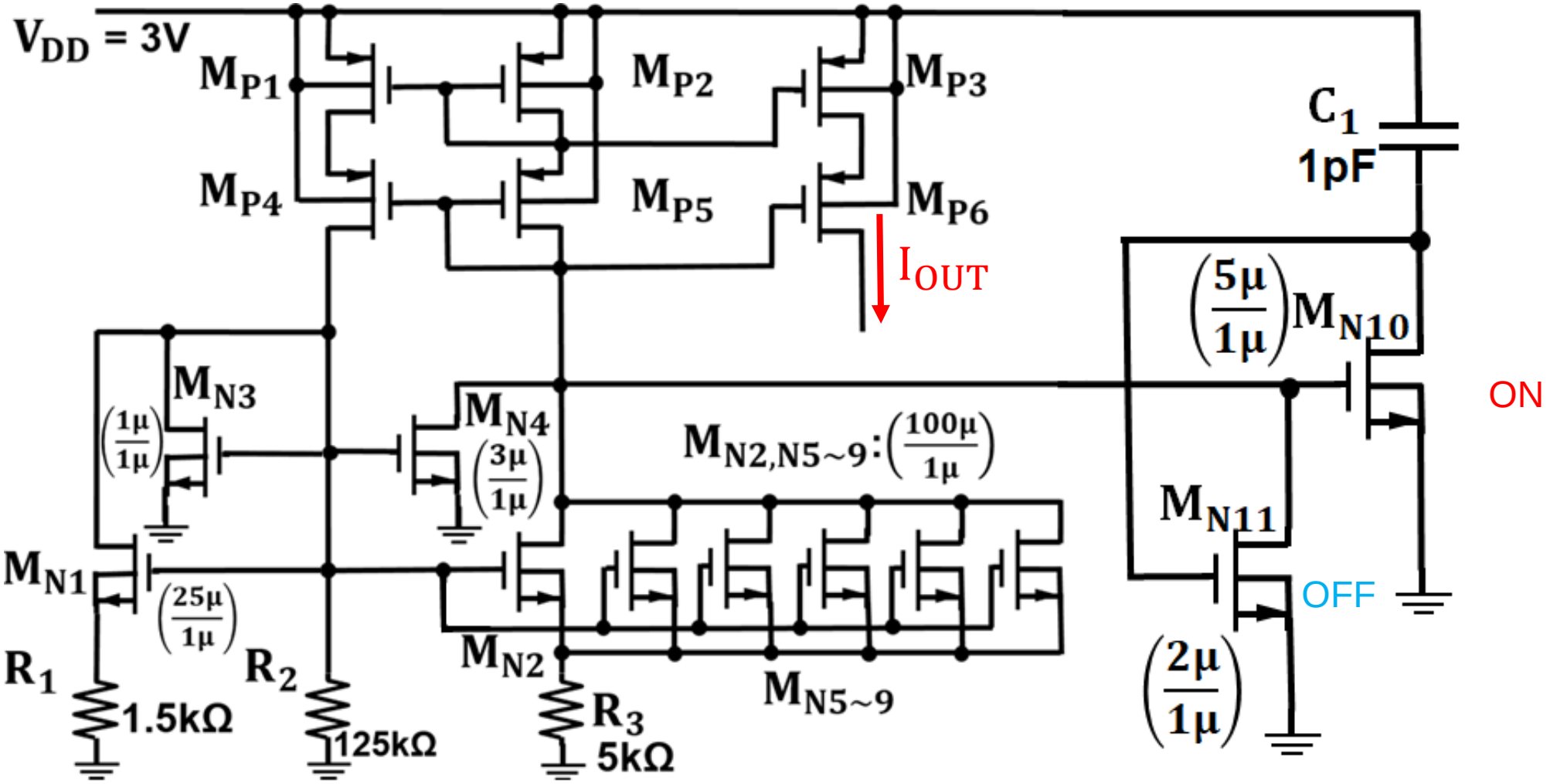
# Operation of Startup Circuit 3 ($M_{N10}$ ON)



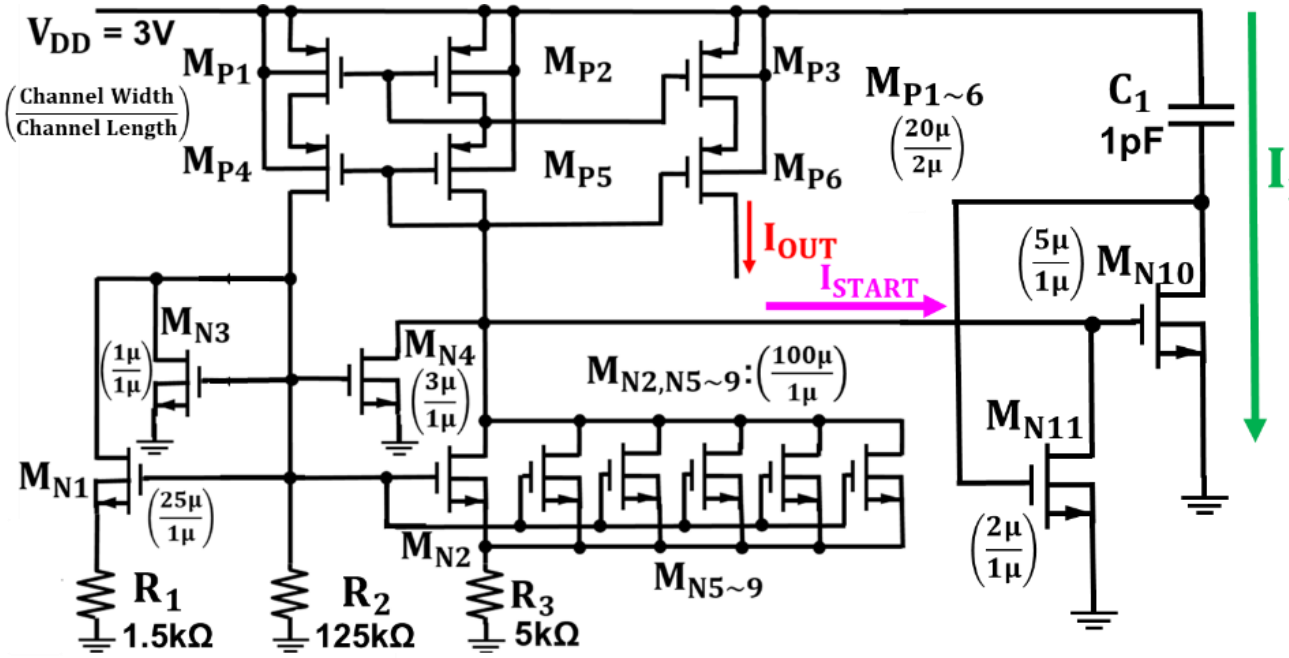
# Operation of Startup Circuit 3 ($C_1$ discharged)

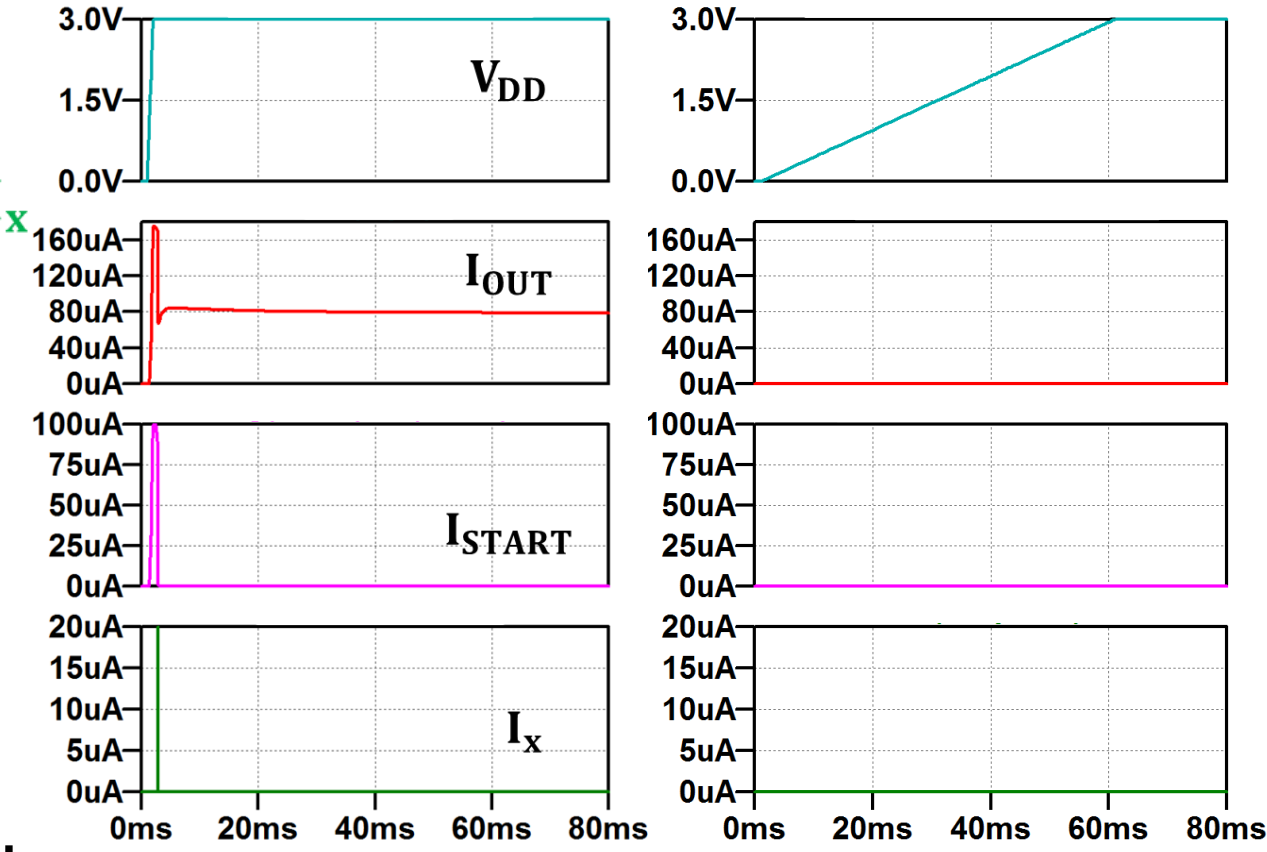


# Operation of Startup Circuit 3 ($M_{N11}$ OFF)



# Merit and Demerits of Startup Circuit 3




$V_{DD}$ rise time = 1ms

$V_{DD}$ rise time = 60ms

**Capacitor model : GCH1555C1H1R0CE01**
**of Murata Manufacturing Co., Ltd.**

**Merit** 😊
- Reduction in power consumption (If the rise of $V_{DD}$ is fast)

**Demerits** 😭
- Increase in chip area
- Problem of startup certainty

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# Conclusion and Challenges

## Conclusion

- **The following table shows a comparison of startup circuits.**

| Types of startup circuits | Chip area | Power consumption | Startup certainty |
|---|---|---|---|
| Startup circuit 1 | Good | Poor | Good |
| Startup circuit 2 (CMOS inverter usage) | Fair | Fair | Good |
| Startup circuit 3 (Capacitor usage) | Poor | Good | Poor |

**Each startup circuit has its own advantages and disadvantages.**
**It is necessary to select the optimal startup circuit according to the application of the proposed circuit.**

## Challenges

- **Implementing a prototype chip.**

# Acknowledgements

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JEDAT® Japan EDA Technologies

群馬大学 GUNMA UNIVERSITY

Kobayashi Laboratory

**Thank you very much**