Temperature-Insensitive MOS Reference Current Source and its Startup Circuit

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Outline

- Introduction
- Research Background
- Temperature-Insensitive

  MOS Reference Current Source Circuit
- Startup Circuit
- Conclusion
- References

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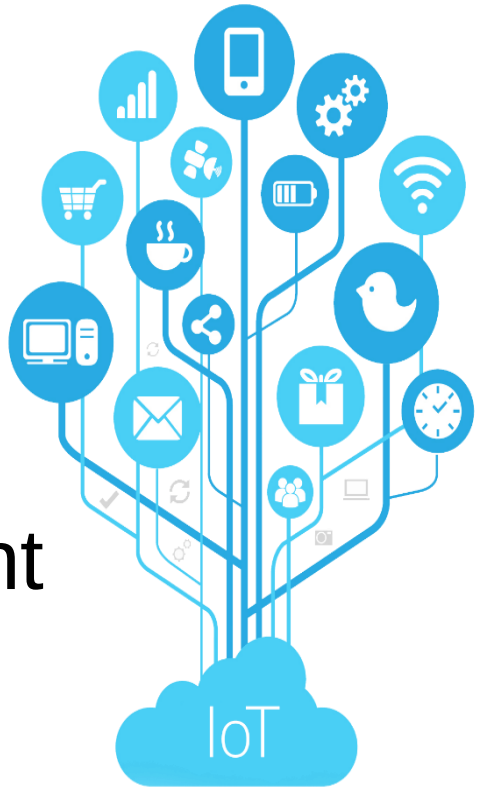
IoT Era and Electronic Devices

IoT (Internet of Things)



Increase of electronic equipment

Demand for high reliability electronic products

Reliability Problem in Electronic Circuits

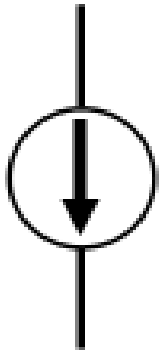
- Process
- Voltage
- Temperature

Reference current source

Provides a constant current to analog circuits regardless of PVT variation

What is a reference current source?

Stable current source against PVT variations



At least one required in an analog IC

Reference current source → Polar star

Today's purpose

Robustness to temperature variation

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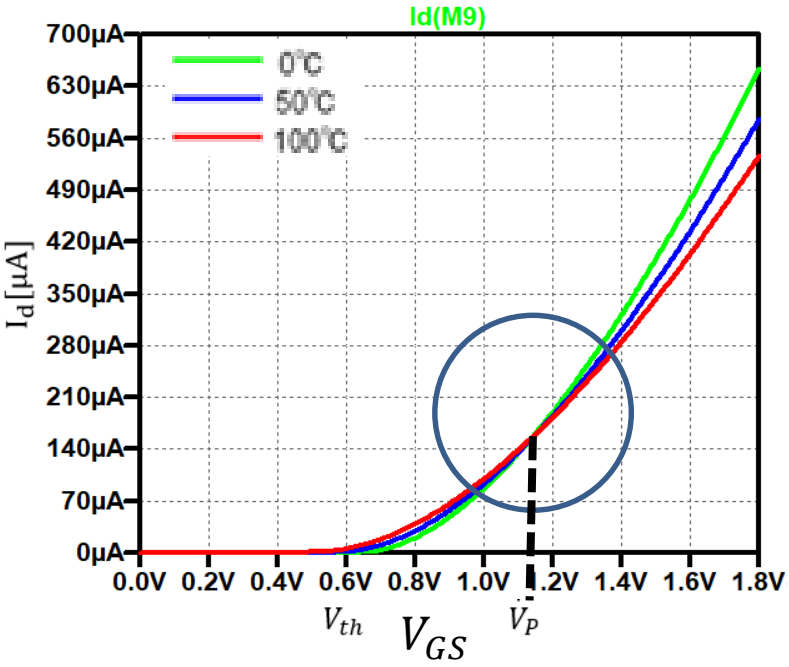
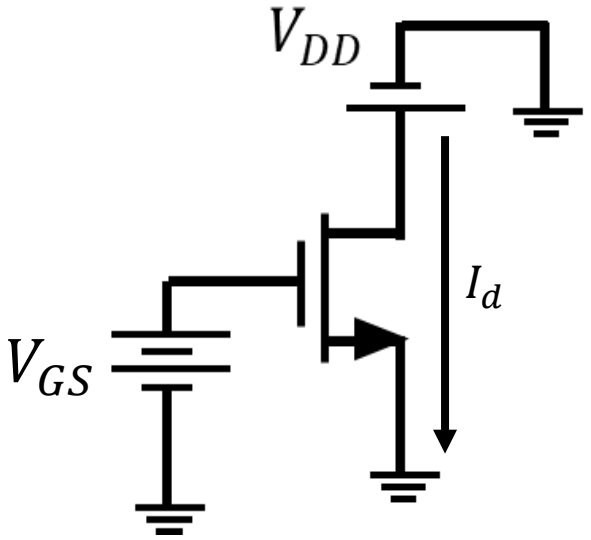
Temperature characteristics of MOSFET



Parameter	Value
V_{GS}	0~1.8[V]
V_{DD}	5.0[V]
M_{NMOS}	W = 20 [μm], L = 2.0 [μm]



Simulation Circuit

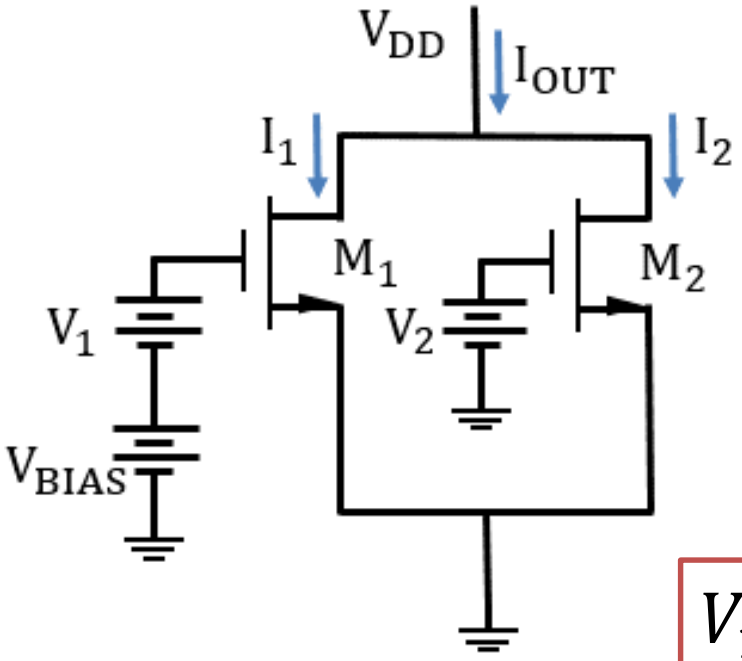
Temperature : High

$V_{GS} < V_P$: Drain current→ Increase

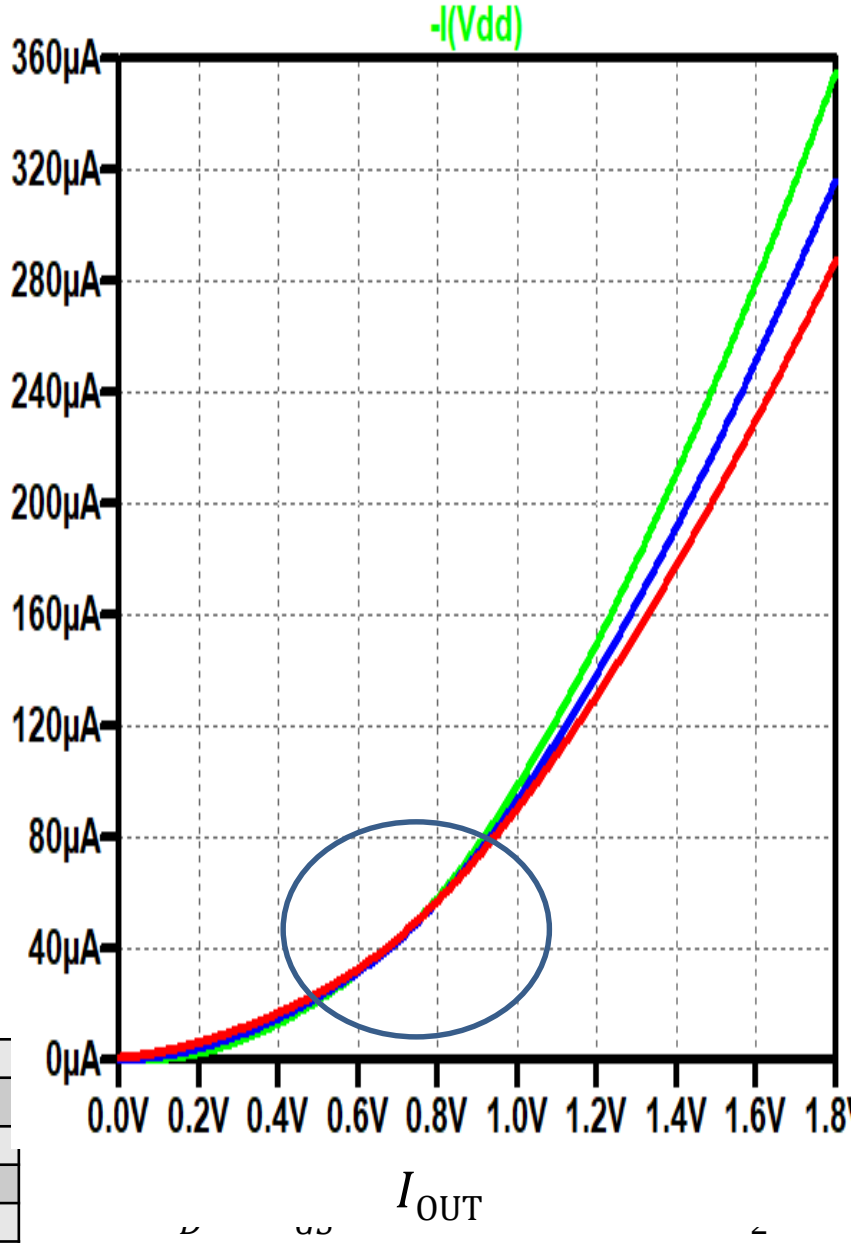
$V_{GS} > V_P$: Drain current→ Decrease

Concept of proposed circuit

Applied different gate voltages of two NMOSFETs in parallel

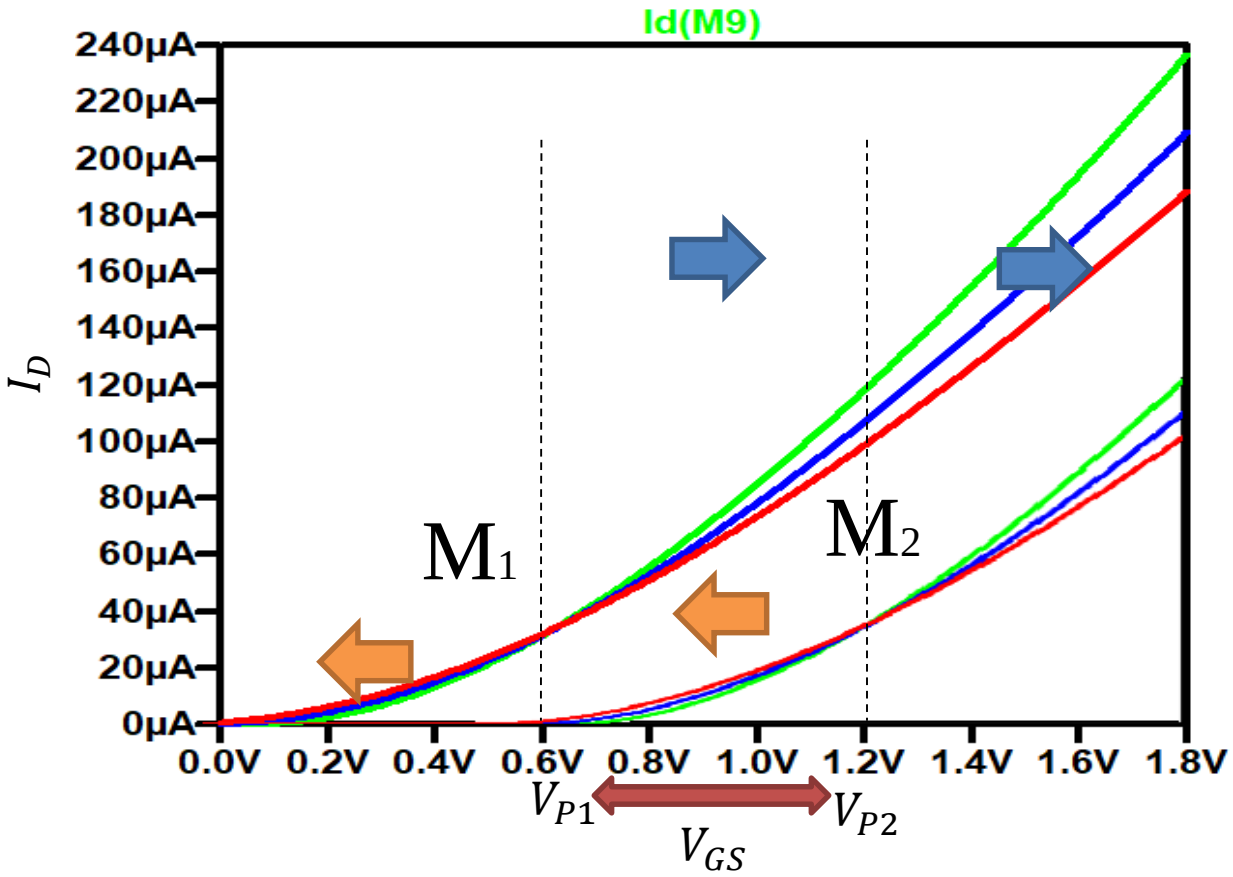


$V_1 > V_2$



Parameter	Value
V_1V_2	0~1.8[V]
V_{BIAS}	0.6[V]
V_{DD}	5.0[V]
M_1,M_2	W = 4 [μm], L = 2 [μm]

Circuit constraints



Current Increase with high temperature

Current Increase with Low temperature

Provides a constant current regardless of temperature

Cancel temperature characteristic

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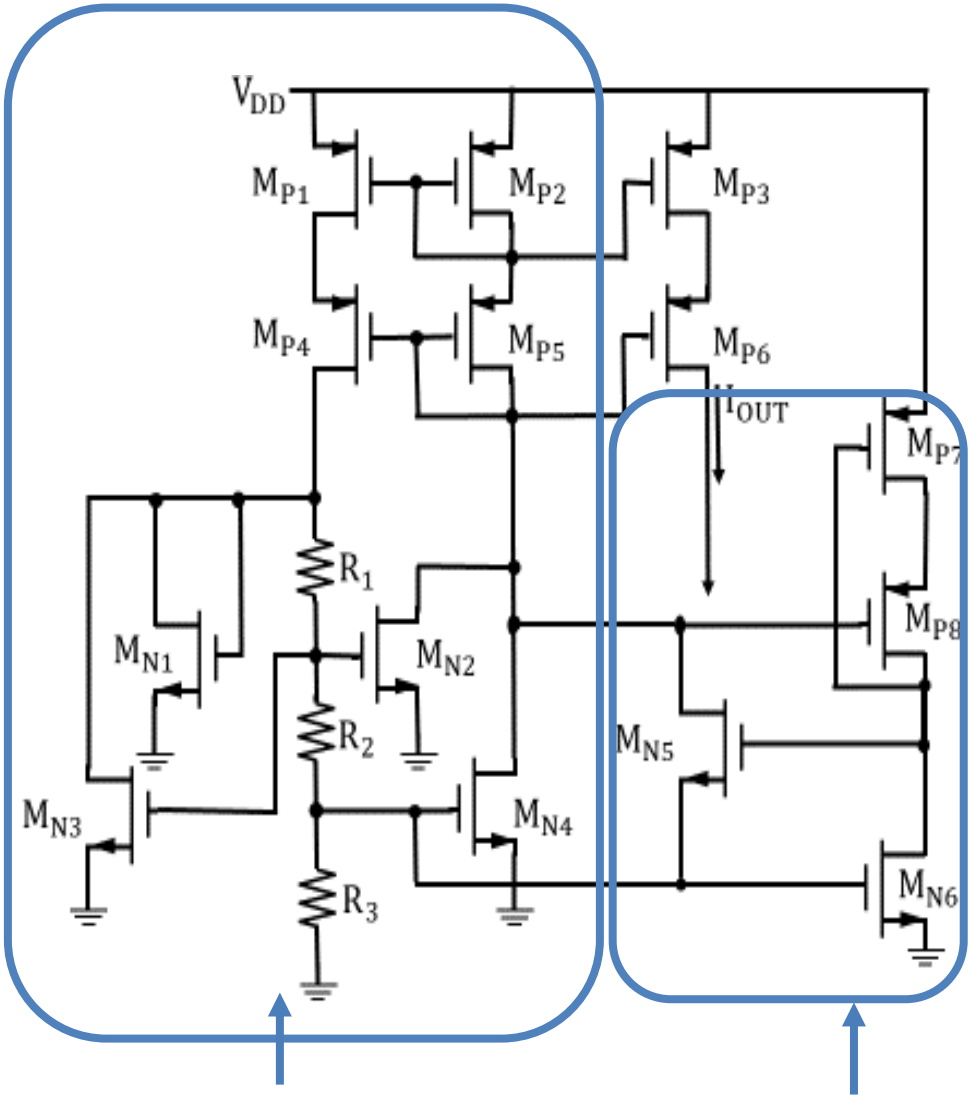
Proposed Circuit

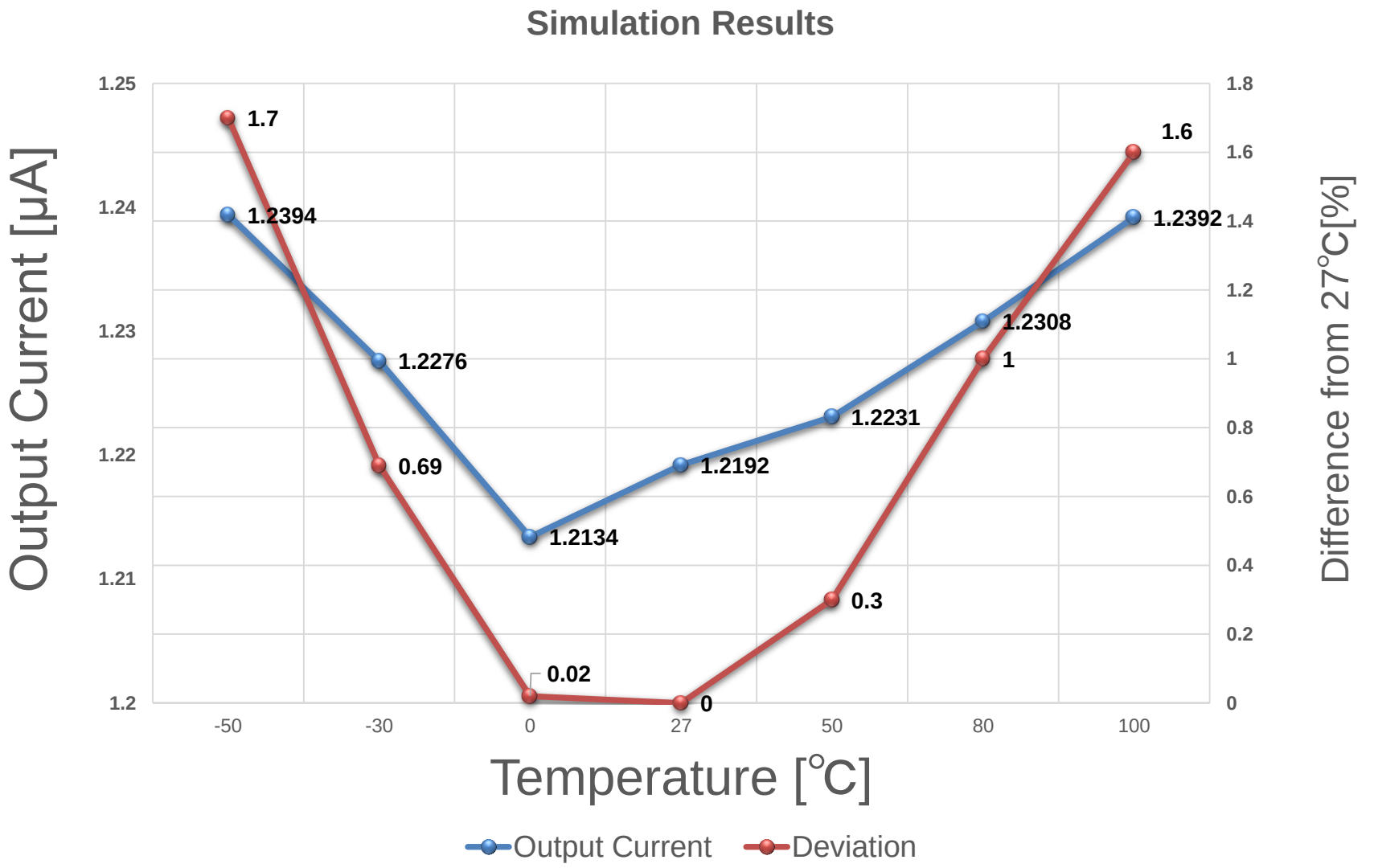


Parameter	Value
$M_{P1} \sim M_{P6}$	W = 800 [μm] , L = 2 [μm]
M_{N1}, M_{N3}, M_{P7}	W = 0.1 [μm], L = 2 [μm]
M_{P8}	W = 2 [μm], L = 2 [μm]
M_{N6}	W = 4 [μm], L = 2 [μm]
M_{N2}	W = 20 [μm], L = 2 [μm]
M_{N5}	W = 25 [μm], L = 2 [μm]
M_{N4}	W = 200 [μm], L = 2 [μm]
R_1	5000 [Ω]
R_2	1610 [Ω]
R_3	1500 [Ω]
V_{DD}	5 [V]

Temperature-Insensitive
MOS Reference Current Source

Startup circuit

Simulation results



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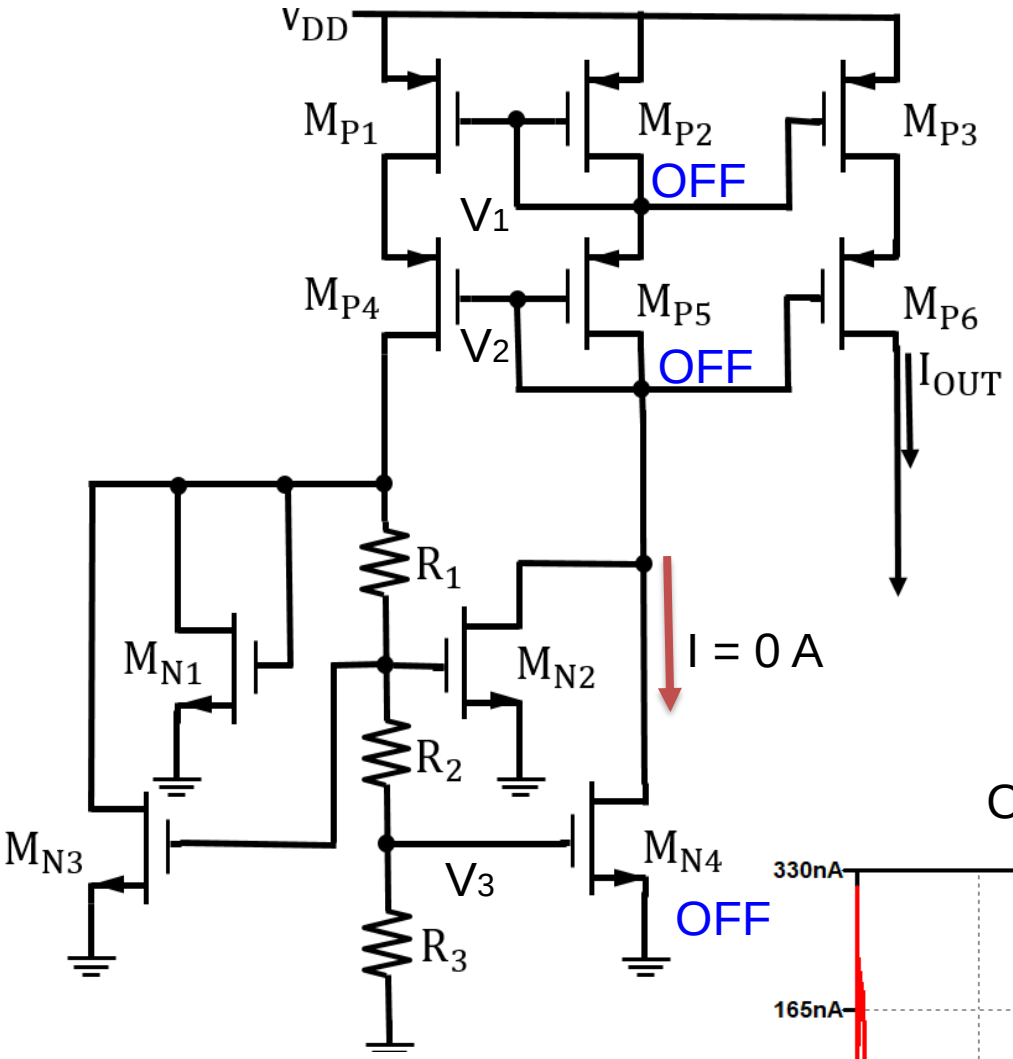
If NOT Use Startup Circuit



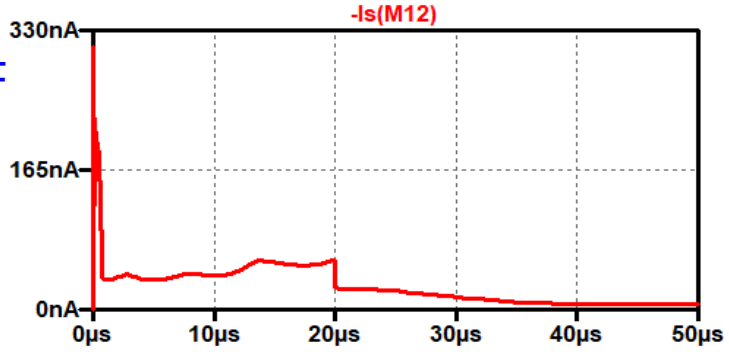
$V_1, V_2 \fallingdotseq V_{DD}$

$V_3 \fallingdotseq 0\ V$

Nothing happens

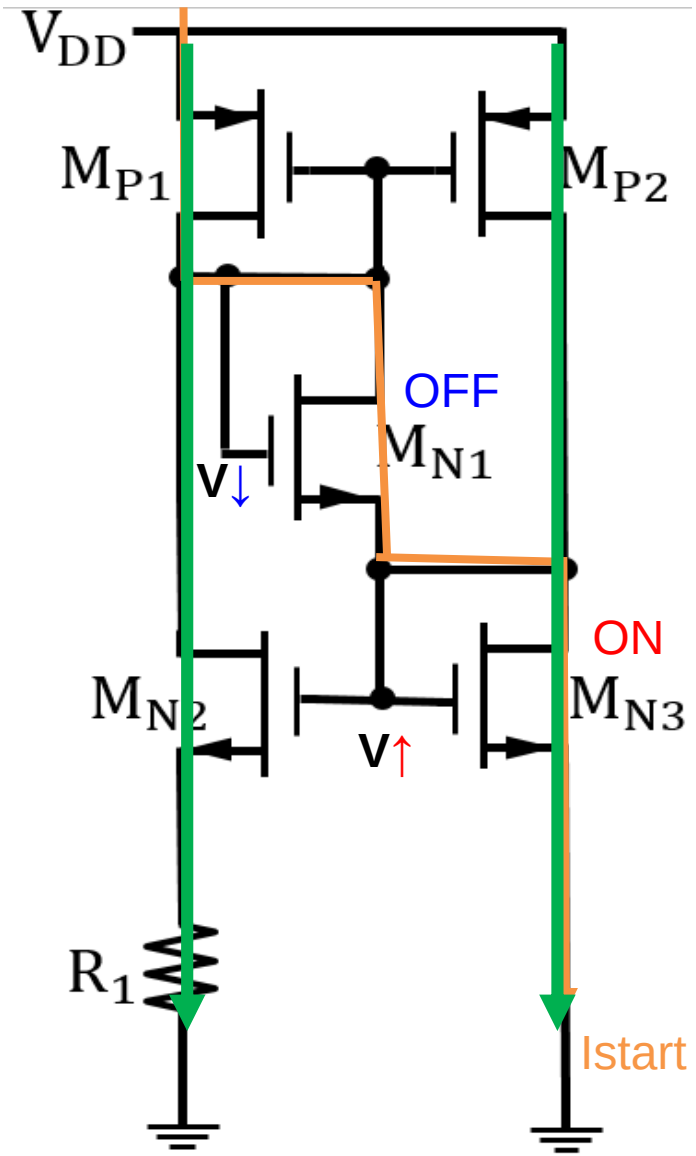
Need Startup Circuit

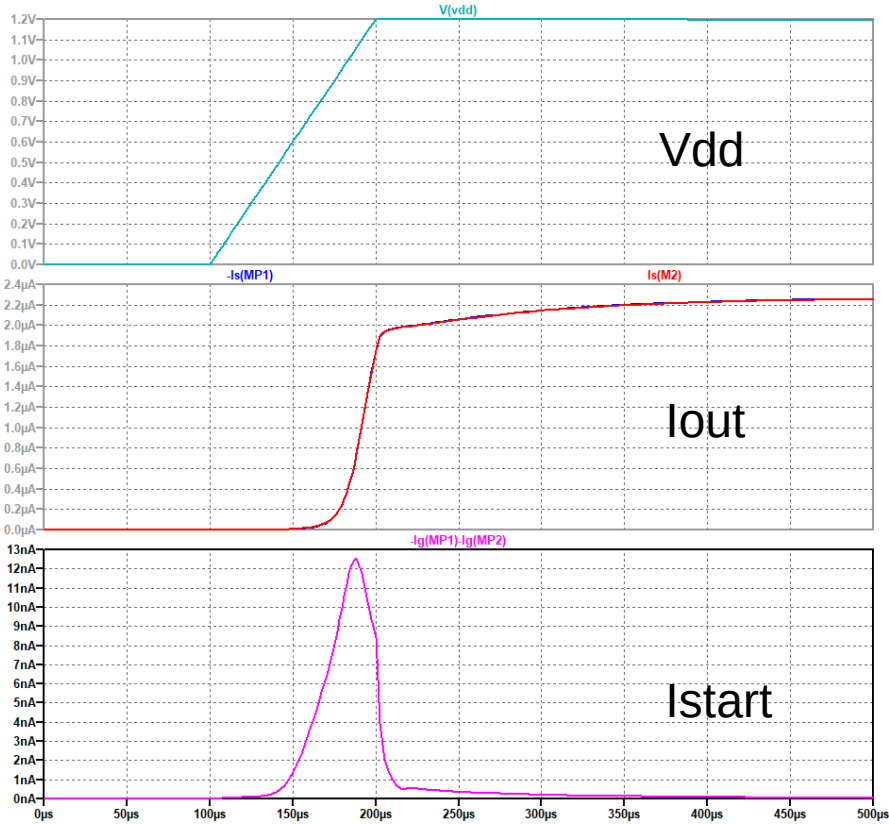
Output current



$I_{OUT} \fallingdotseq 0\ A$

Simple Startup Circuit 1

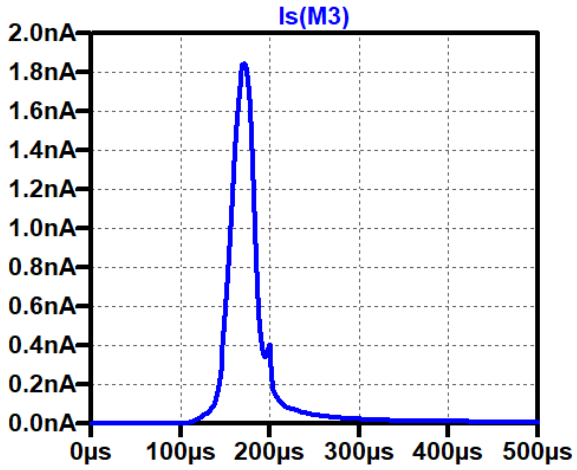




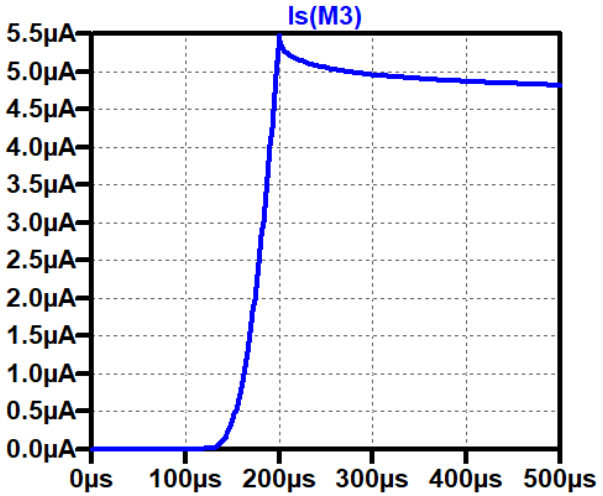
Parameter	Value
M_{P1} , M_{P2}	W = 10 [μm] , L = 10 [μm]
M_{N1}, M_{N2}, M_{N3}	W = 1 [μm], L = 1 [μm]
R_1	500 [Ω]
V_{DD}	1.2 [V]

Problems of Startup Circuit 1

- Need to turn off the MN1 after starting the constant current circuit
- Cannot be used to widen the use range of the power supply voltage

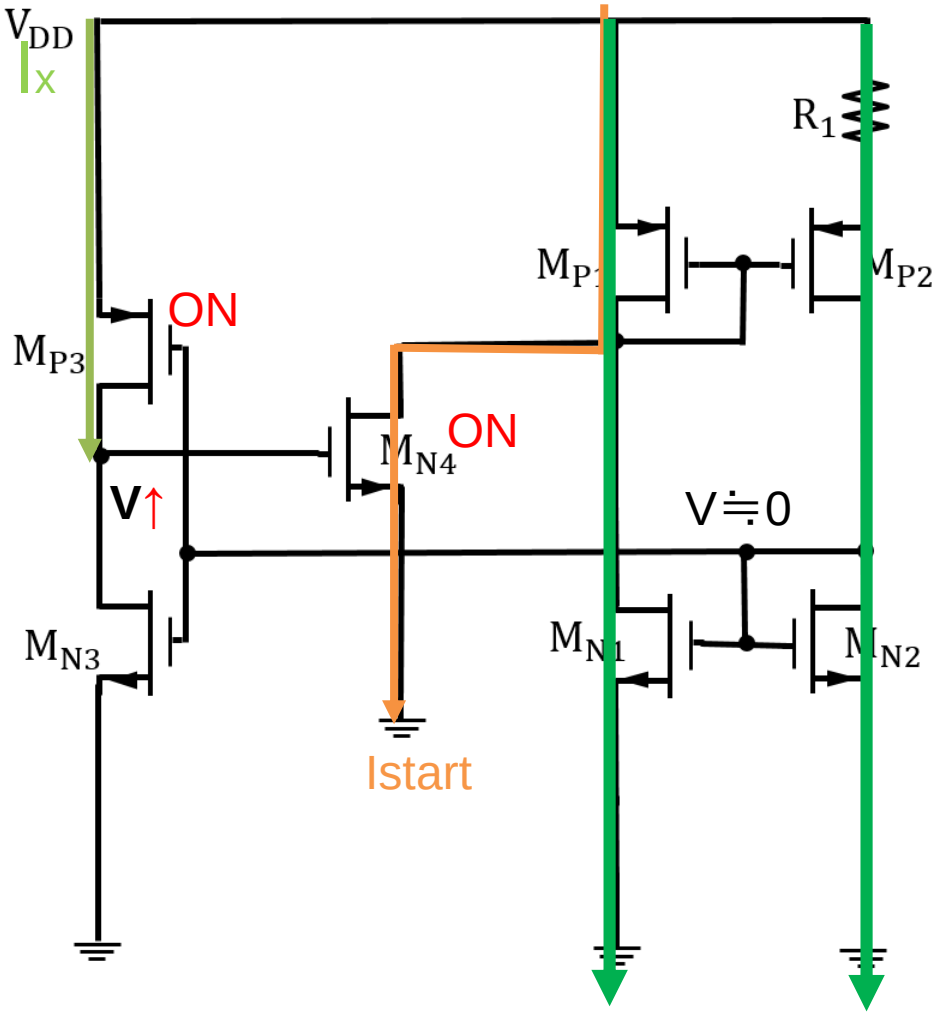


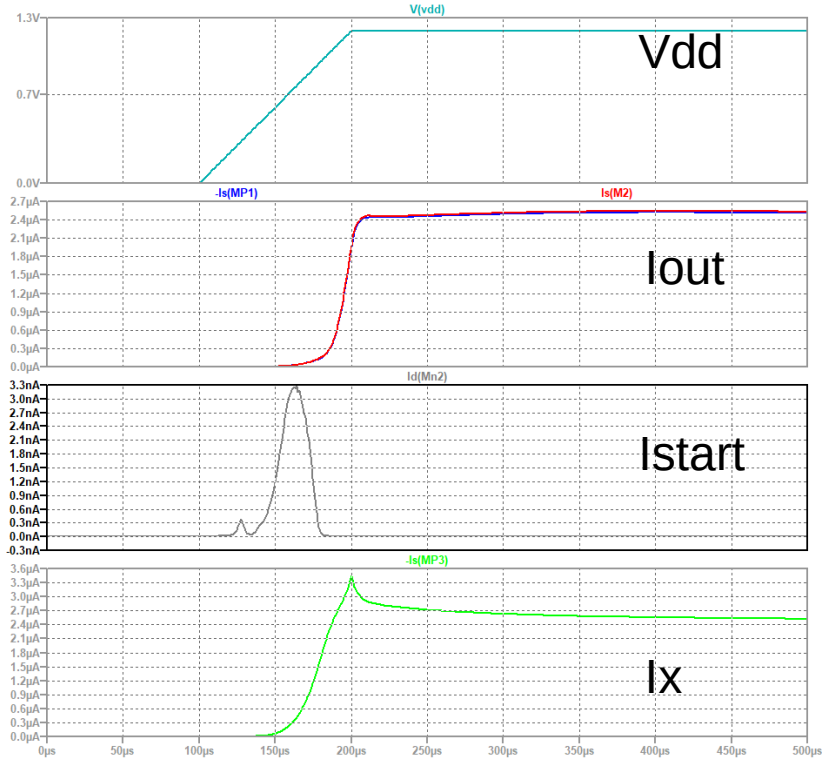
Vdd 1.2V



Vdd 5V

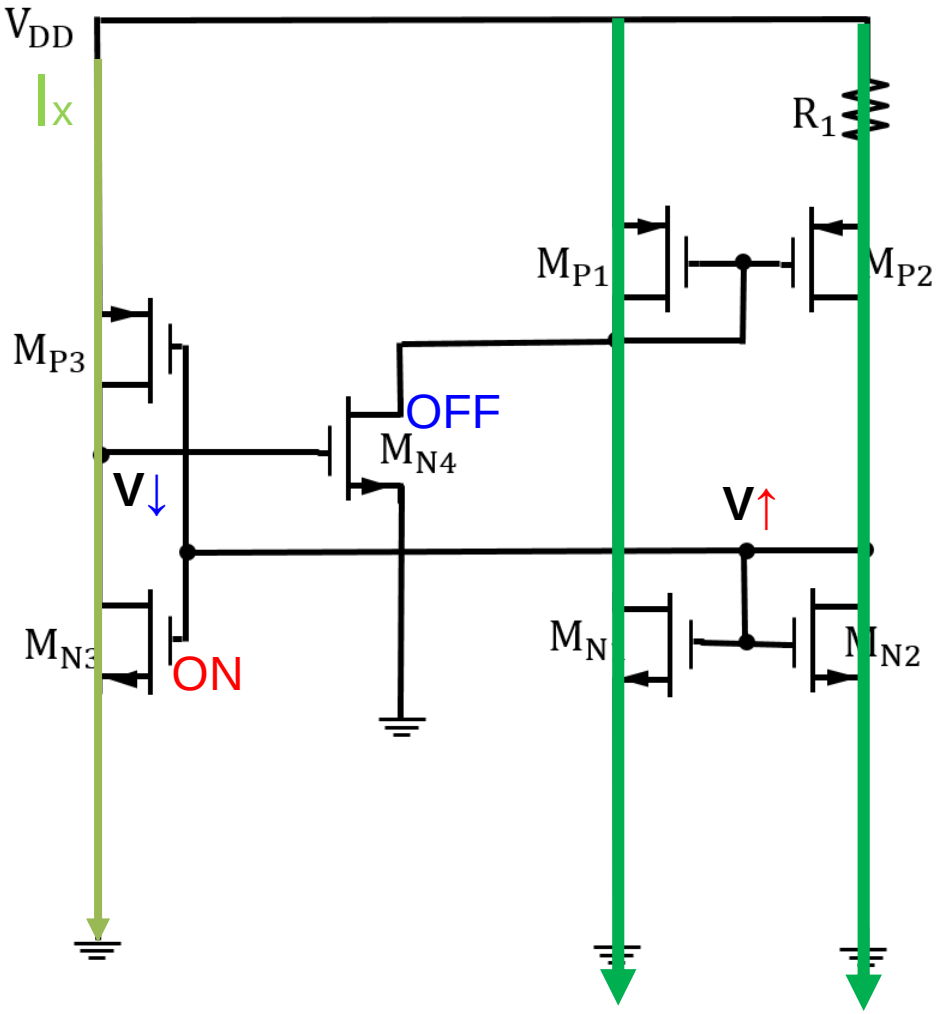
Simple Startup Circuit 2

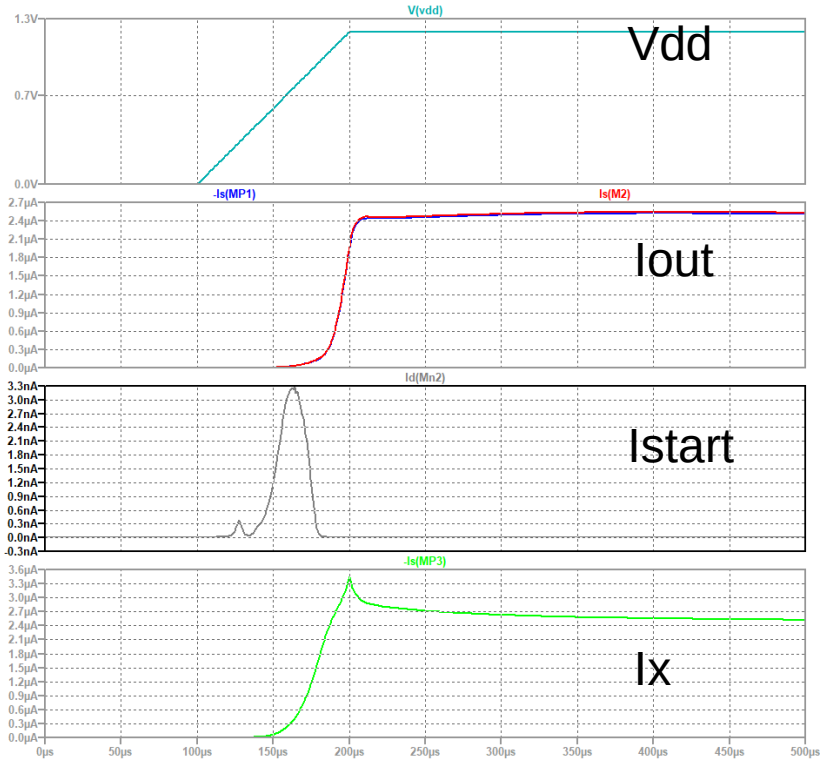




Parameter	Value
M_{P1} ,M_{P2}	W = 10 [μm] , L = 10 [μm]
M_{N1}, M_{N2}, M_{N4}, M_{P3}	W = 0.1 [μm], L = 1 [μm]
M_{N3}	W = 10 [μm], L = 1 [μm]
R_1	500 [Ω]
V_{DD}	1.2 [V]

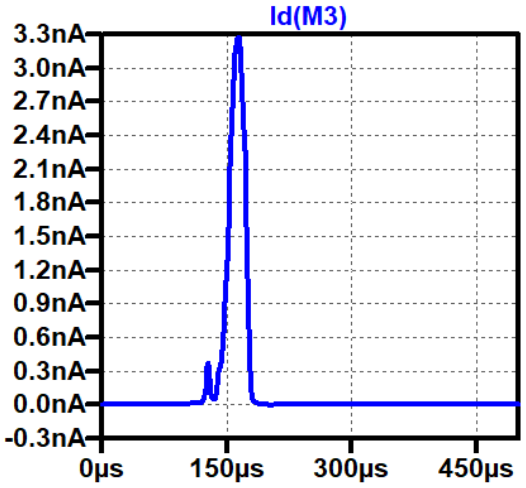
Simple Startup Circuit 2



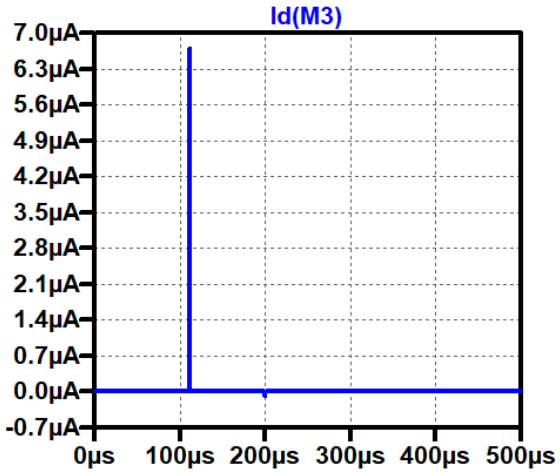


Problems of Startup Circuit 2

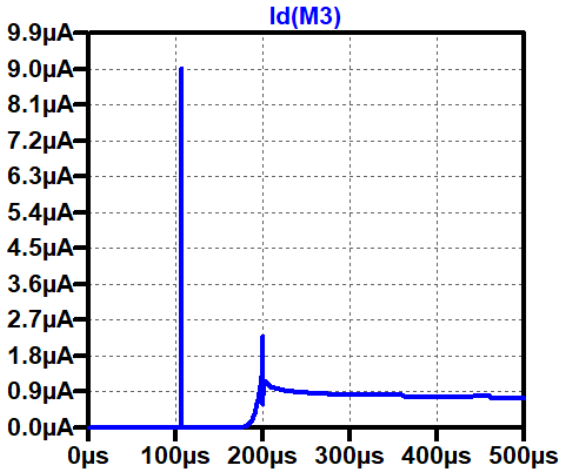
- Can turned off surely as compared with the first case
- An increase in the power supply voltage is limited
- Need to limit current Ix flowing through the M_{P3}



Vdd 1.2V

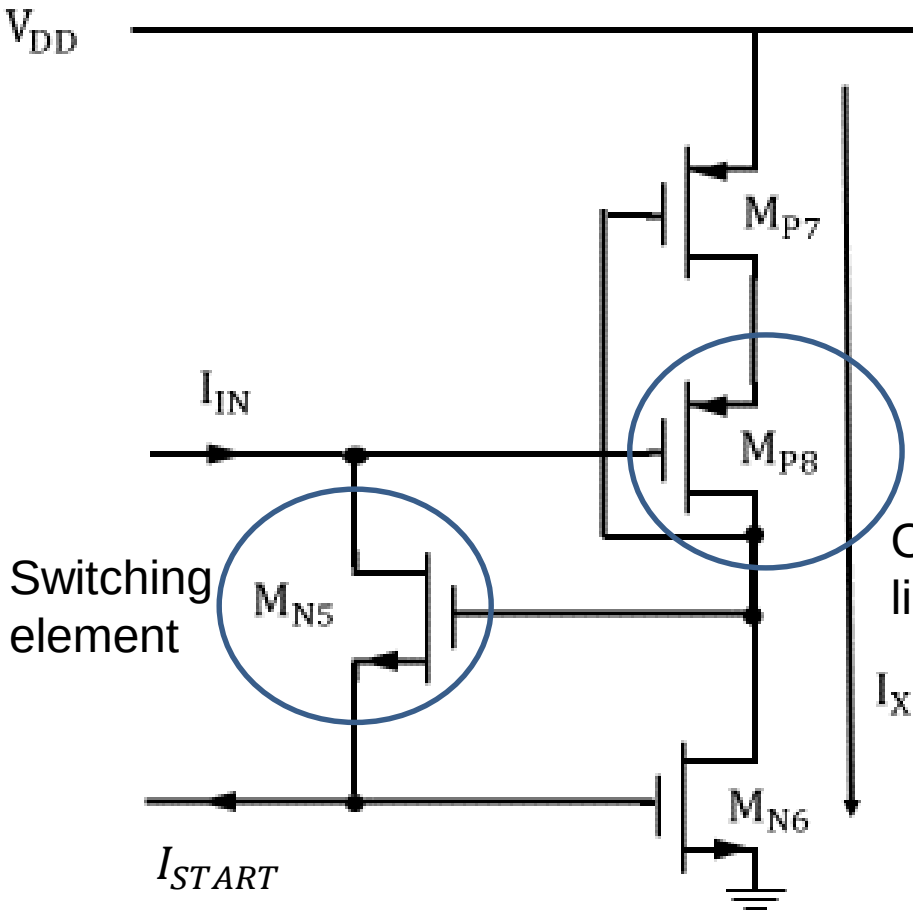


Vdd 5V



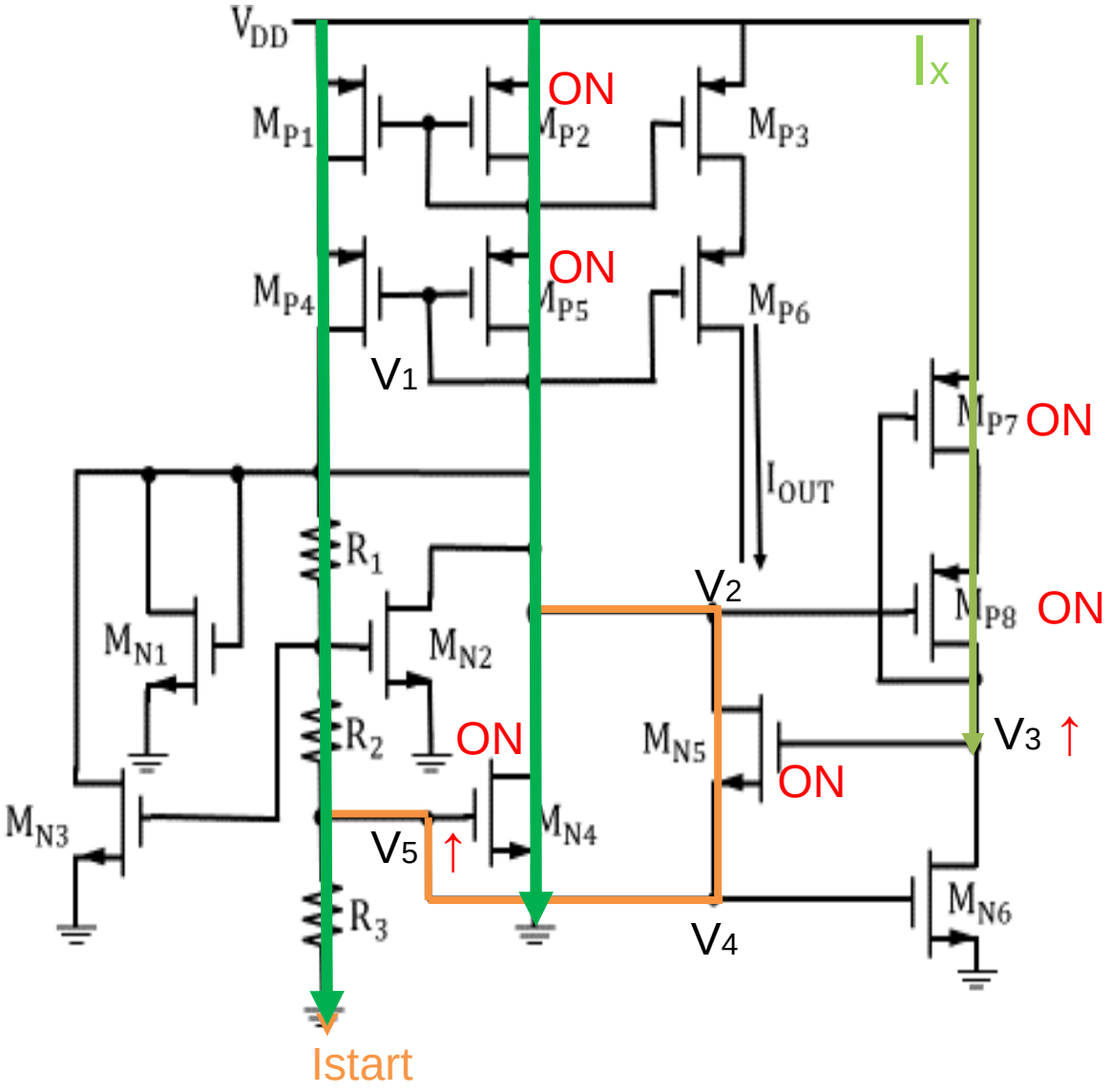
Vdd 10V

Our Design of Startup Circuit



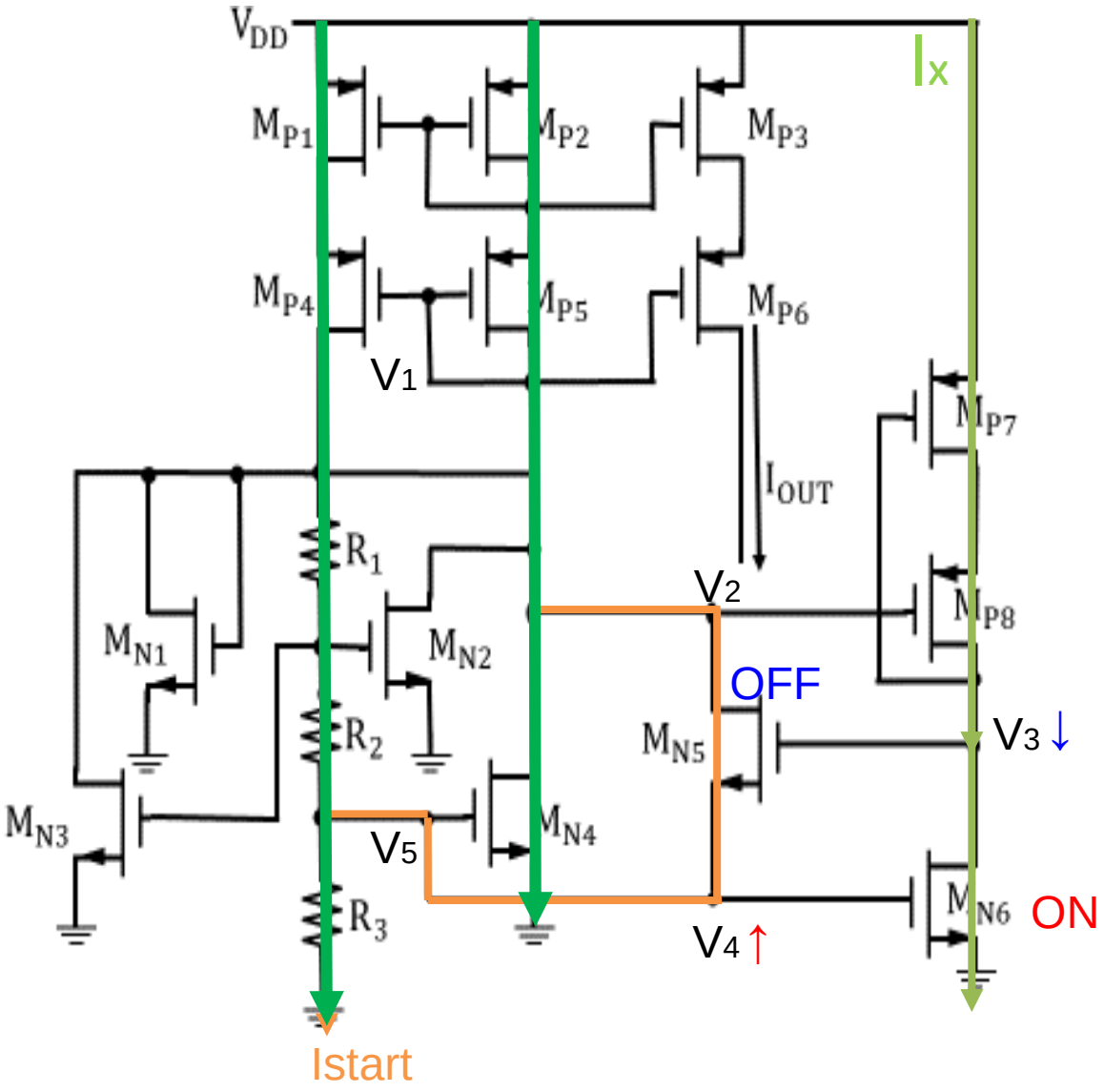
Parameter	Value
M_{P7}	W = 0.1 [μm], L = 2 [μm]
M_{P8}	W = 2 [μm], L = 2 [μm]
M_{N6}	W = 4 [μm], L = 2 [μm]
M_{N5}	W = 25 [μm], L = 2 [μm]
V_{DD}	5 [V]

Before Power Turn ON



$V_1 \sim V_5 \fallingdotseq 0V$

After Power Turn OFF



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Conclusion

- Proposed Temperature-Insensitive

  MOS Reference Current Source

- Showed circuit operation of startup circuit
- Future Works
  - Stability analysis
  - Power consumption reduction
  - Improve the startup circuit

References

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[2] C. Yoo, J. Park “CMOS Current Reference with Supply and Temperature Compensation”, ***Electronics Letters***, vol. 43, no.25, pp.1422-1424 (Dec. 2007).

[3] H. Ikeda, K. Takakubo, H. Takakubo, “Drain Current Zero-Temperature-Coefficient Point for CMOS Temperature Voltage Converter Operating in Strong Inversion”, ***IEICE Trans. Fundamentals***, Vol. E87-A, No. 2, pp.370-275 (Feb. 2004).

[4] T. Kajita, Startup Circuit U.S. Patent No. 9,960,762

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[7] R. JACOB BAKER “CMOS Circuit Design, Layout, and Simulation, Third Edition” (http://cmosedu.com/cmos1/cmosedu_models.txt)