

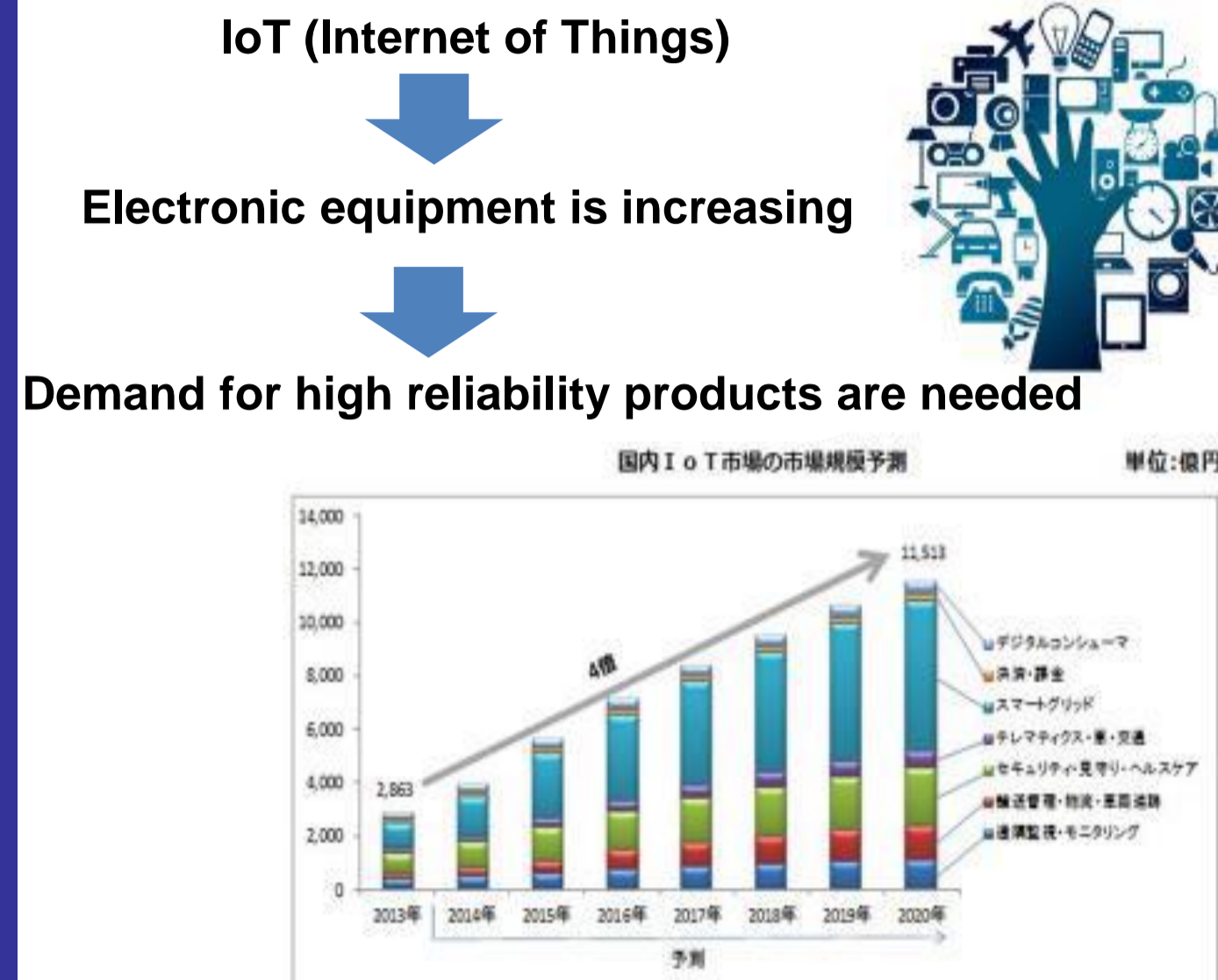
1. Background

Reliability problems in electronic circuits

Provides a constant current to analog circuits regardless of PVT variation

- Process
- Voltage
- **Temperature**

Constant current source



Provides a constant current to analog circuits regardless of PVT variation

At least one required
In an analog IC

Reference current source → The polar star

Today's purpose

Robustness to temperature variation

2. Research Objective

Temperature Characteristics of MOSFET

$$I_d = \frac{W}{L} \mu C_{OX} [(V_{GS} - V_{th})V_{DS} - \frac{1}{2}V_{DS}^2] \dots (1)$$

$$I_d = \frac{W}{2L} \mu C_{OX} (V_{GS} - V_{th})^2 (1 - \lambda V_{DS}) \dots (2)$$

μ : Mobility

V_{th} : Threshold Voltage

$$\mu = \mu_0 (T/T_0)^{-1.5} \dots (3)$$

$$V_{th} = \frac{\sqrt{2eNA\epsilon_{Si}(2\phi_B)}}{C_{OX}} + 2\phi_B + V_{FB} \dots (4)$$

Temperature : High

$$\phi_B = \frac{k_B T}{e} \ln \left(\frac{N_A}{n_i} \right), n_i = N_{exp} \left(-\frac{E_g}{2k_B T} \right) \dots (5)$$

Current : Decrease

$$\frac{dV_{th}}{dT} = -1 \sim -3 [mV/^{\circ}C]$$

Temperature : High

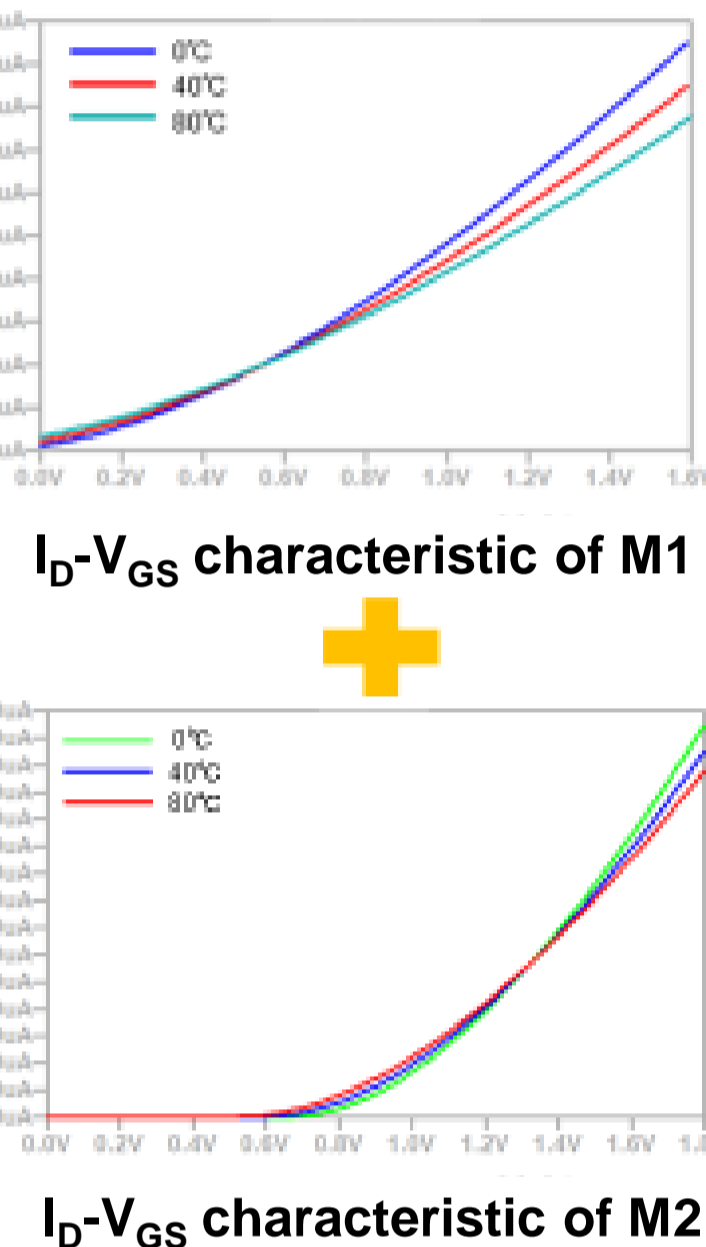
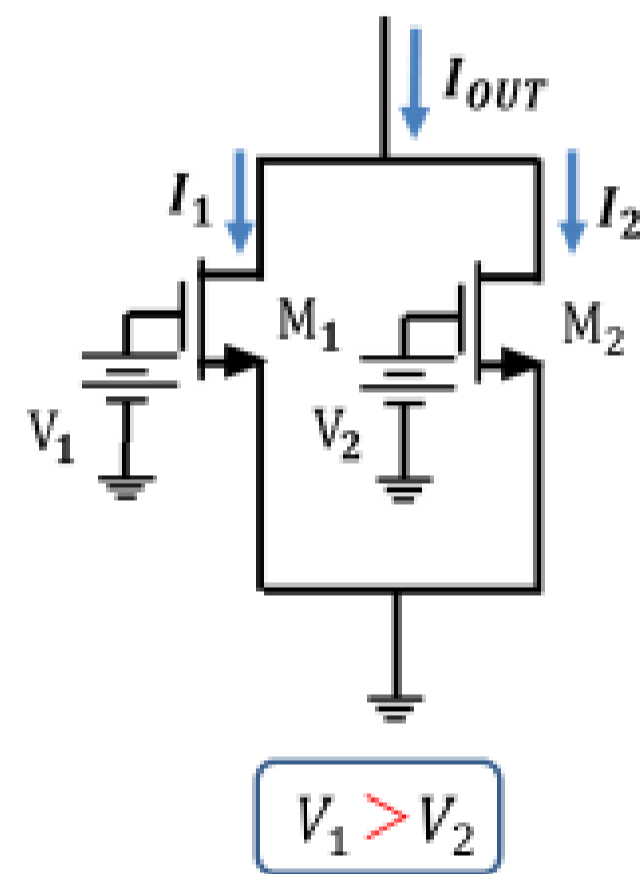
Threshold Voltage : Decline

Φ_B : Built-in potential

n_i : Intrinsic carrier density of the NMOSFET

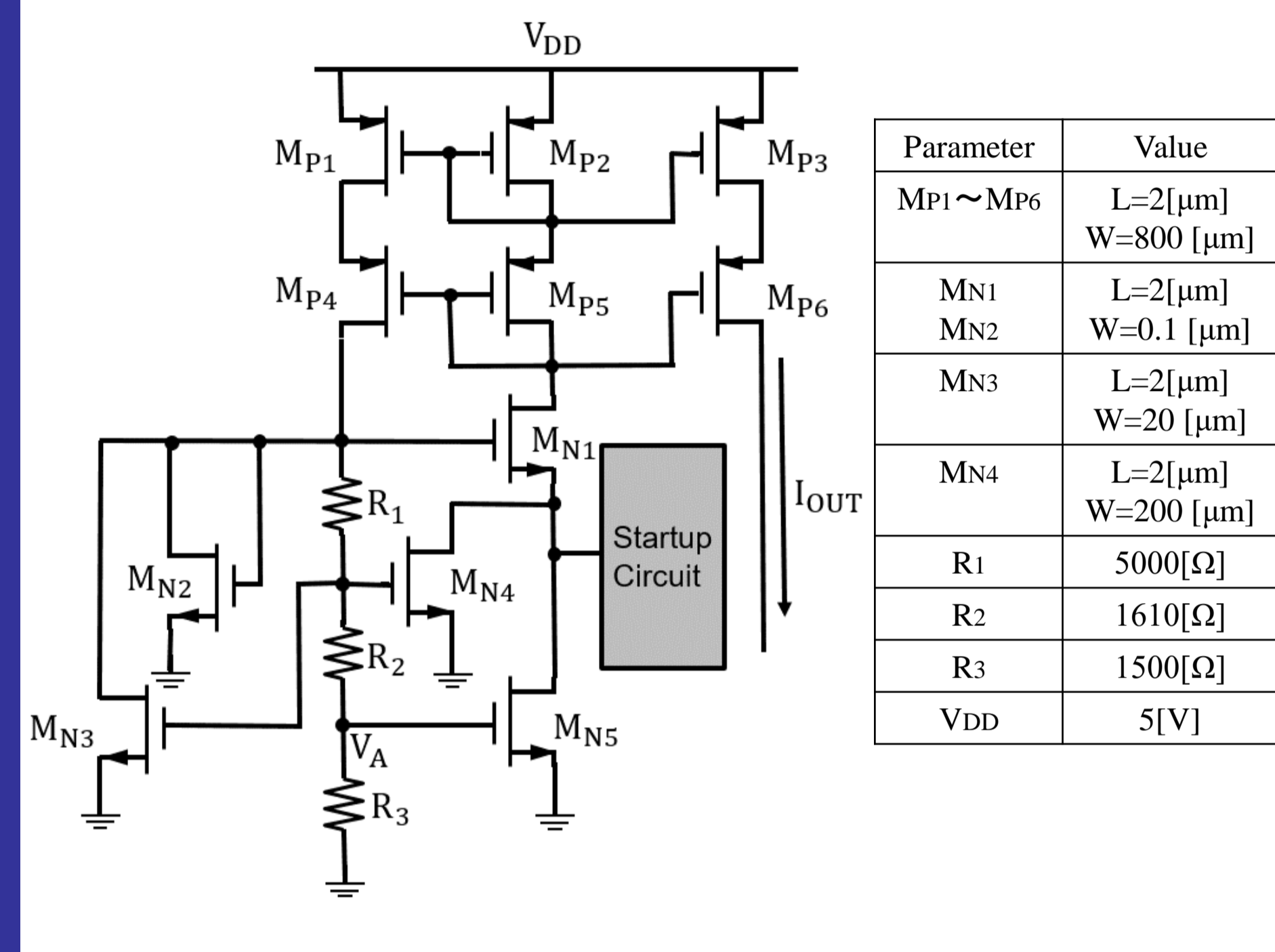
Proposed MOS Reference Current Source Insensitive to Temperature

Concept of proposed circuit
Applied different bias voltages to the gates of the NMOSFETs



3. Proposed Circuit

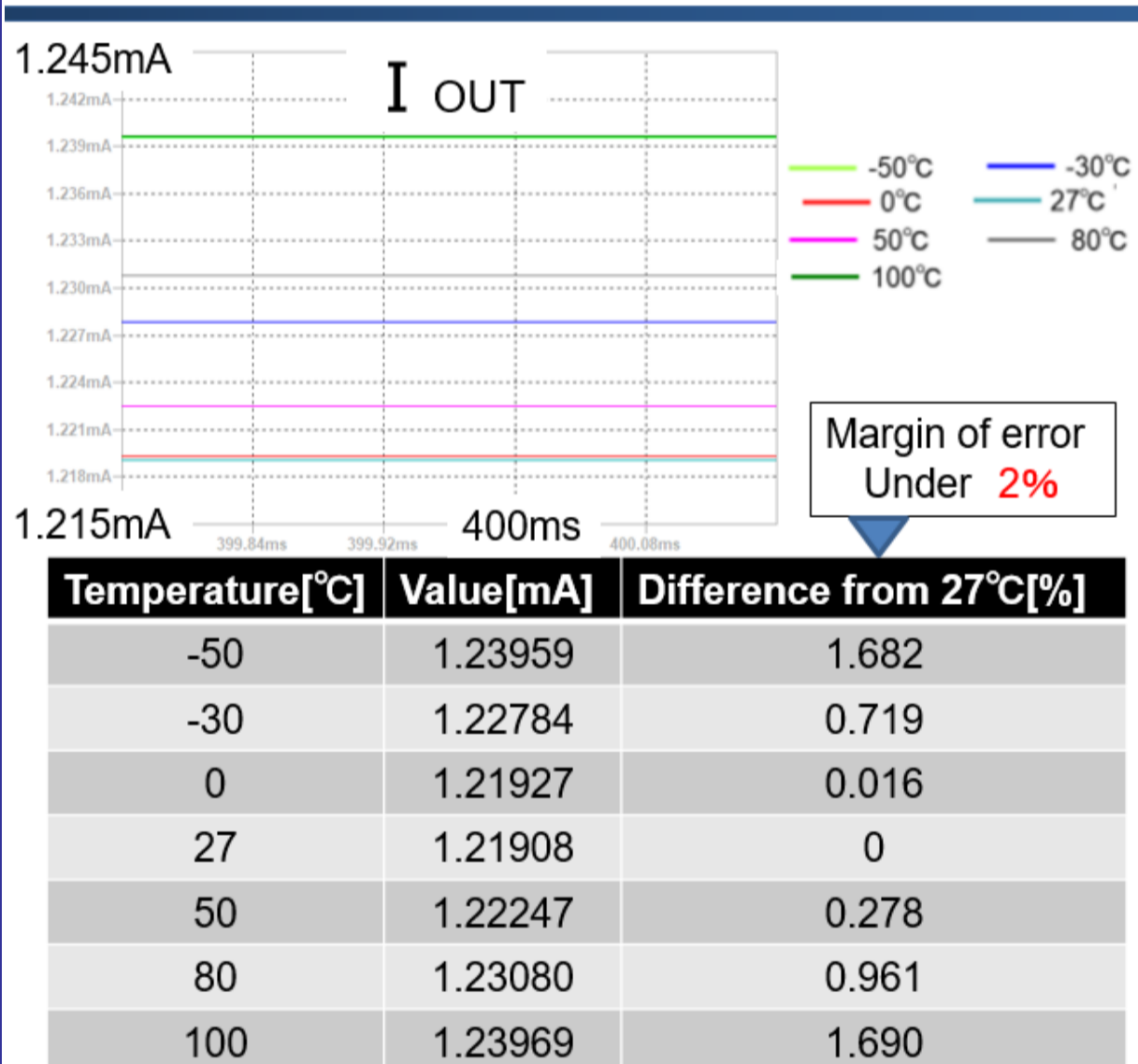
Proposed Circuit



4. Analysis & Design

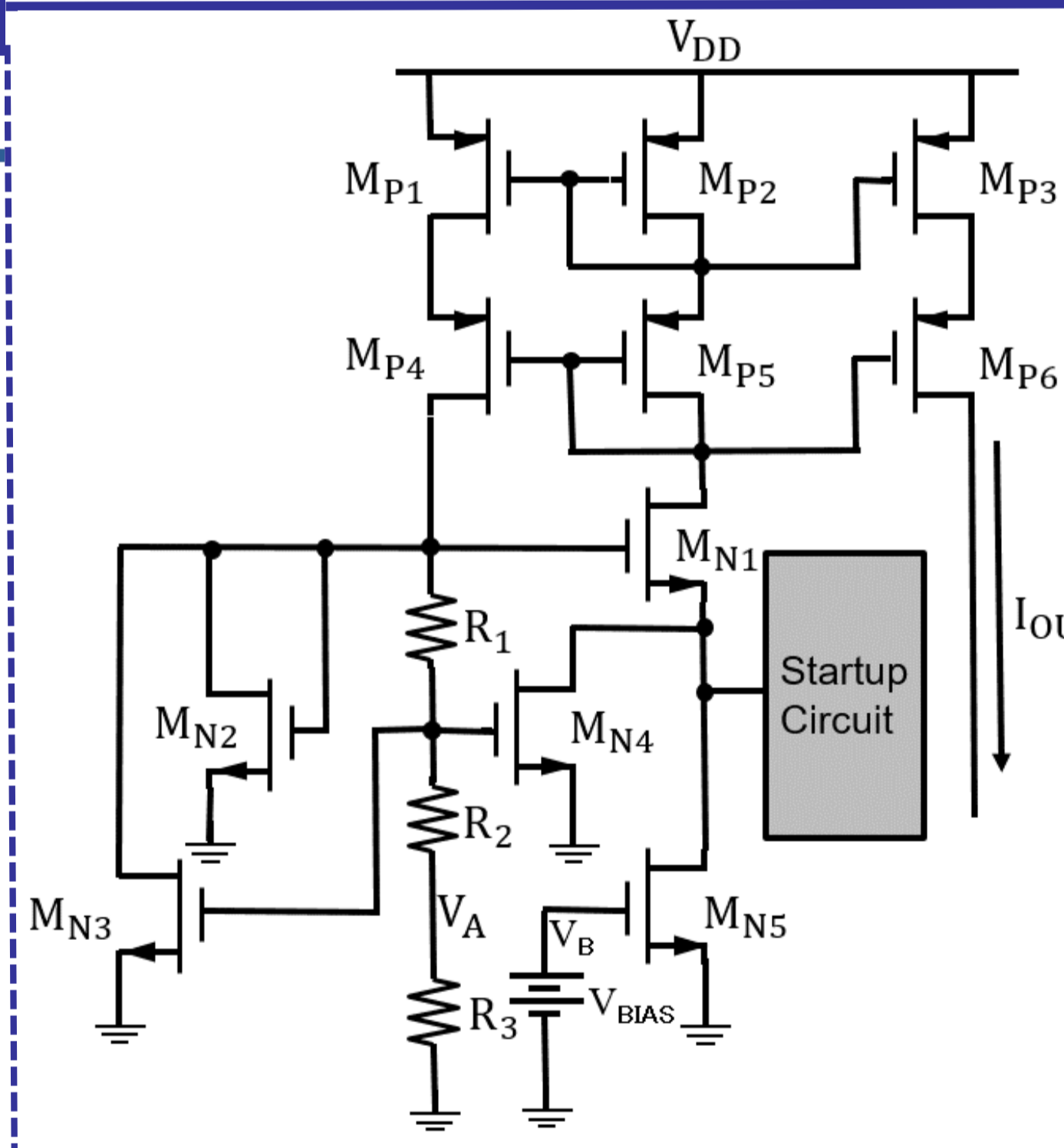
Stability Analysis

Simulation (Proposed Circuit)



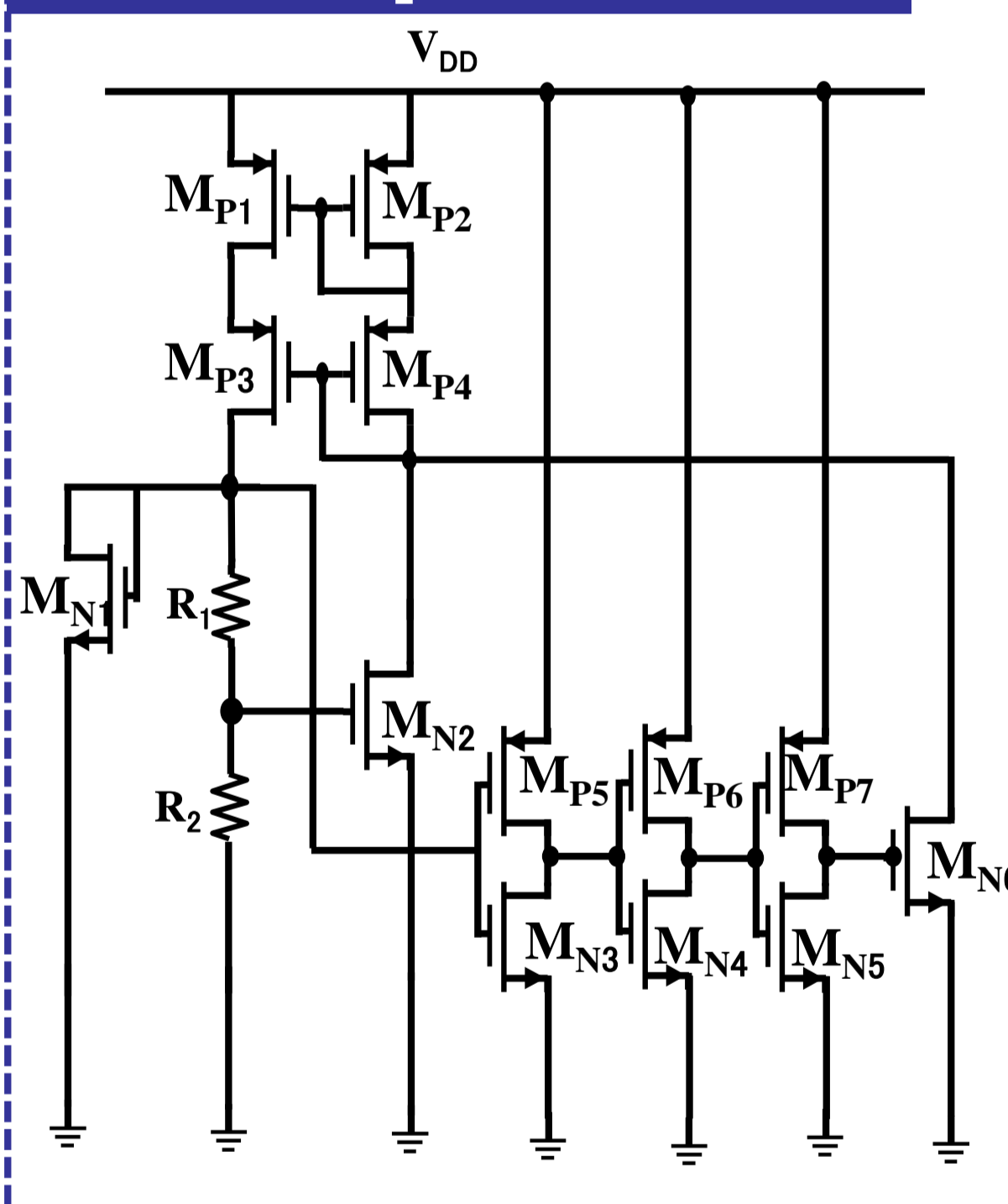
Analyze the stability of Proposed circuit by Stability Analysis Circuit

Stability Analysis Circuit



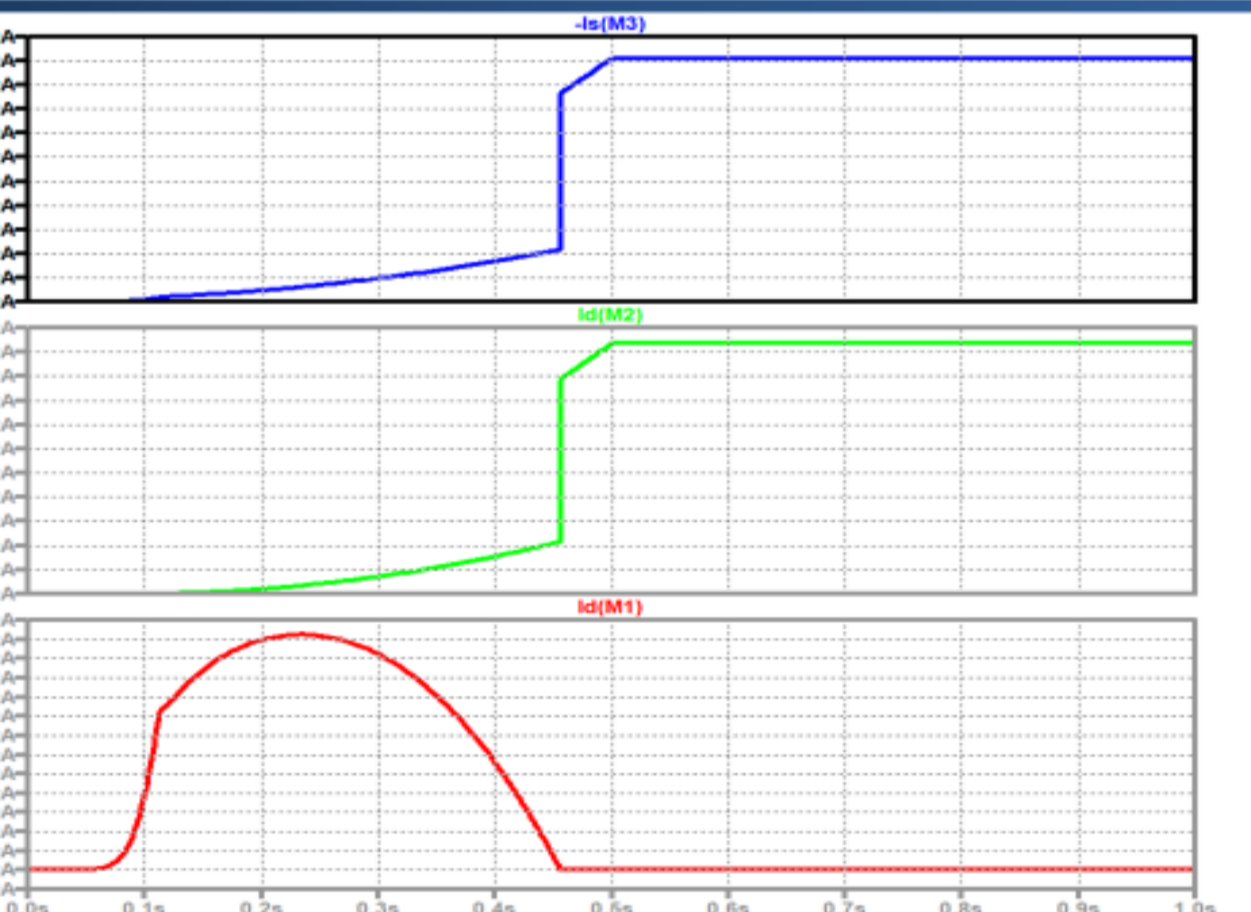
DC Analysis V_{BIAS} : 0V to 5V

Startup Circuit



Transient Analysis Time : 0s to 1s

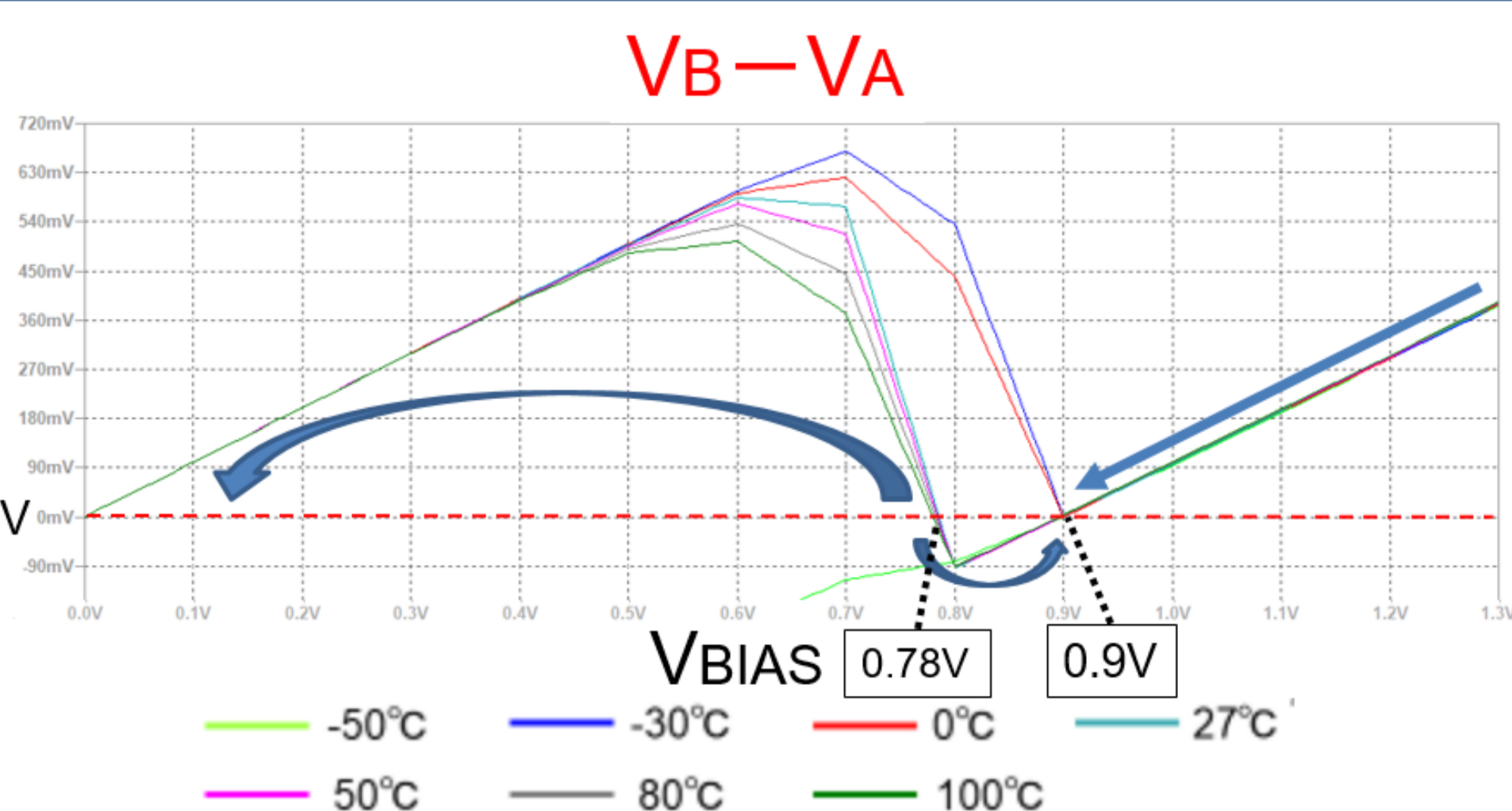
Simulation (Startup Circuit)



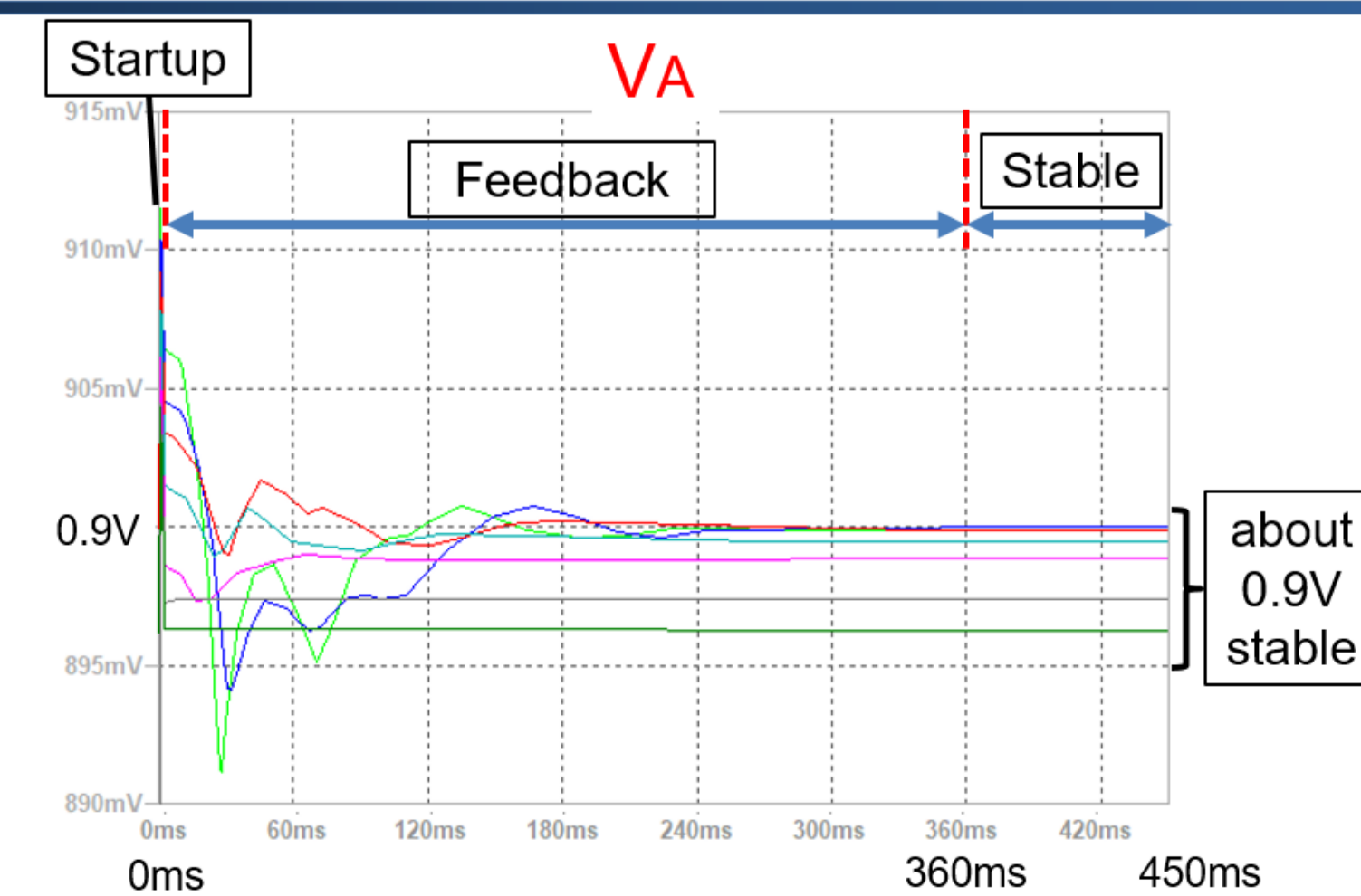
Parameter	Value	Parameter	Value
MP1 ~ MP4	L=3[μm] W=75 [μm]	MN2	L=3[μm]
MN1	L=3[μm] W=3 [μm]	MN6	W=6 [μm]
MN3	L=1[μm]	MN4	L=1[μm]
MN5	W=3 [μm]	MP7	W=1 [μm]
MP5		R1	5[kΩ]
MP6		R2	30[kΩ]
VDD	5[V]		

5. Simulation Verification

Simulation (Stability Analysis Circuit)



Feedback process (Proposed Circuit)



6. Conclusion

- Proposal of temperature-insensitive MOS reference current source circuit.

• Show its configuration and effectiveness with SPICE simulation.

• Analyze its stability

• Realize start-up circuit using CMOS Inverters

- Future work

• Improvement the circuit

for lower-supply voltage insensitivity .