Analog Circuit Session 1

Oct. 23, 2020
15:00 - 15:15

Operation and Stability Analysis of Temperature-Insensitive MOS Reference Current Source with Self-Bias Circuit

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Outline

- Research Background
- MOS Drain Current

  Temperature Characteristics
- Temperature-Insensitive Current Source
- Proposed Circuit using Self-Bias
- Stability Verification
- Conclusion

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- **Research Background**
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Research Background

Reliability issues in electronic circuits

- Process
- Voltage
- Temperature

We focus on

Temperature-insensitive current source

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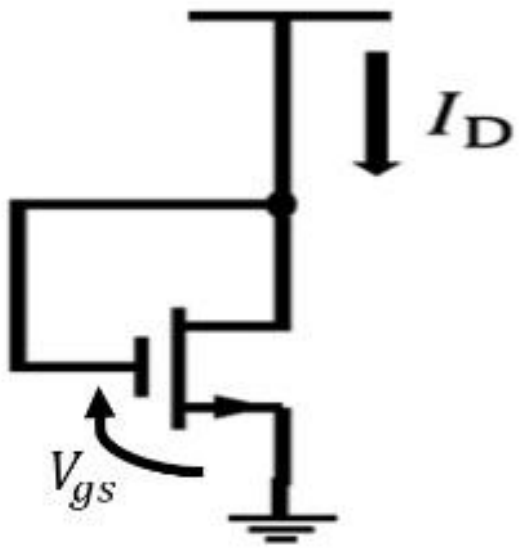
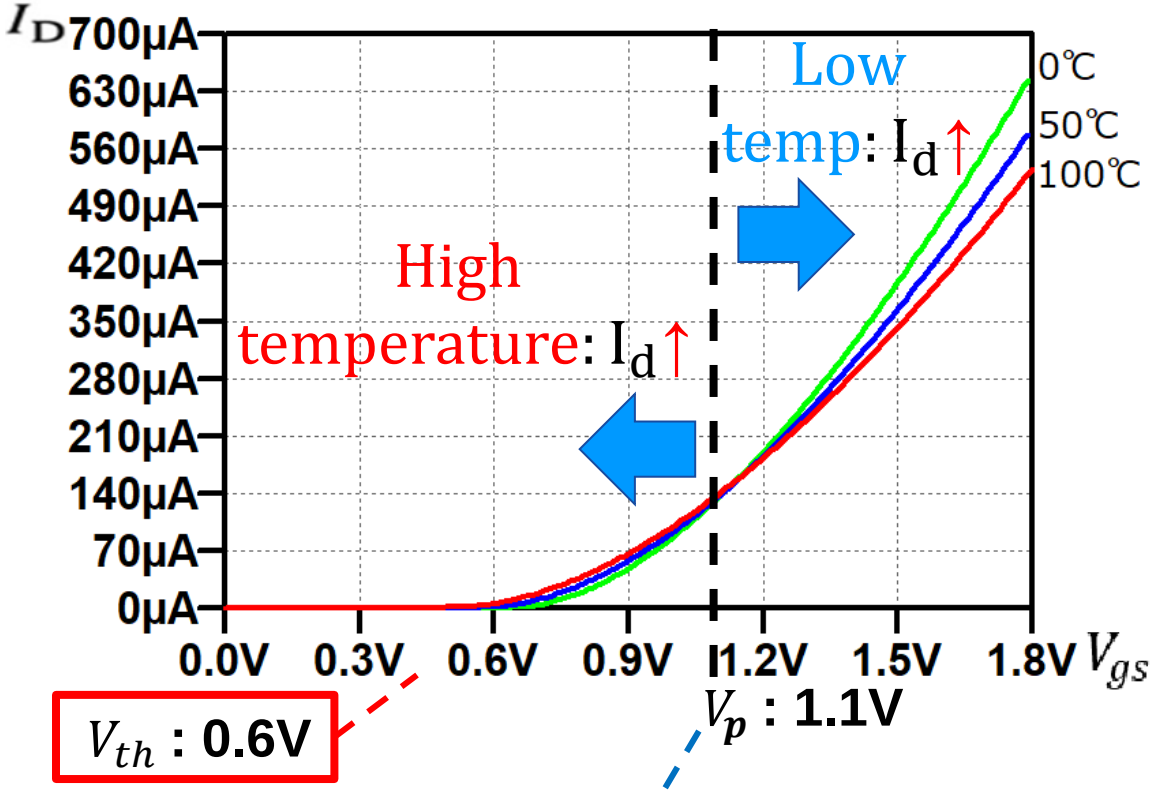
MOS Drain Current and Gate Voltage

Simulated drain current temperature characteristics





Gate voltage: Drain current is fixed against temperature change

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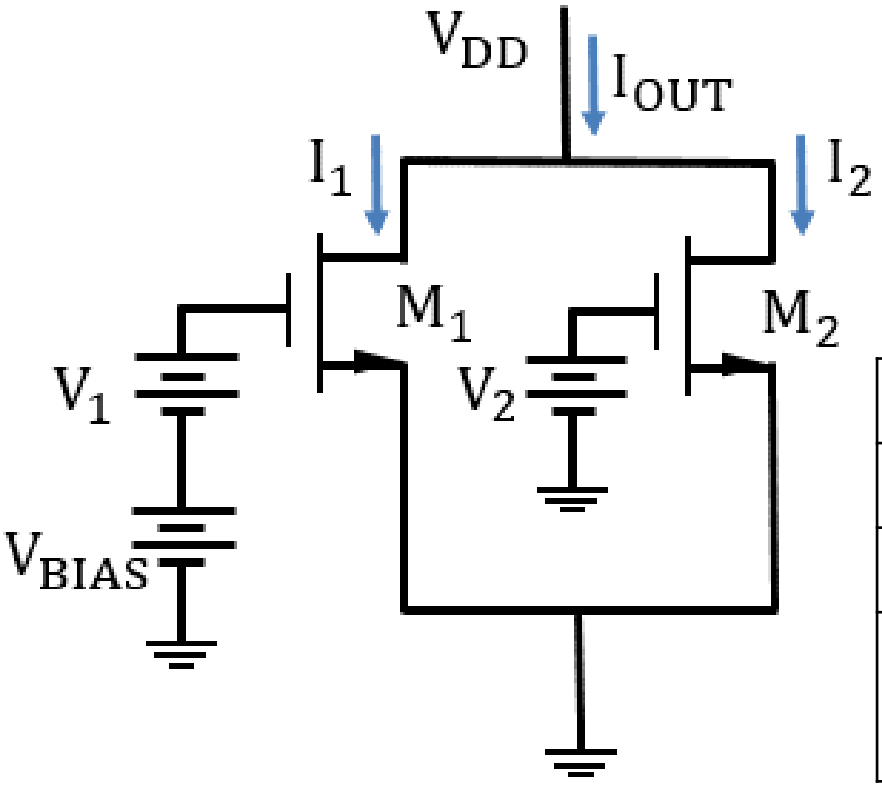
Concept of Temperature-Insensitive Current Source

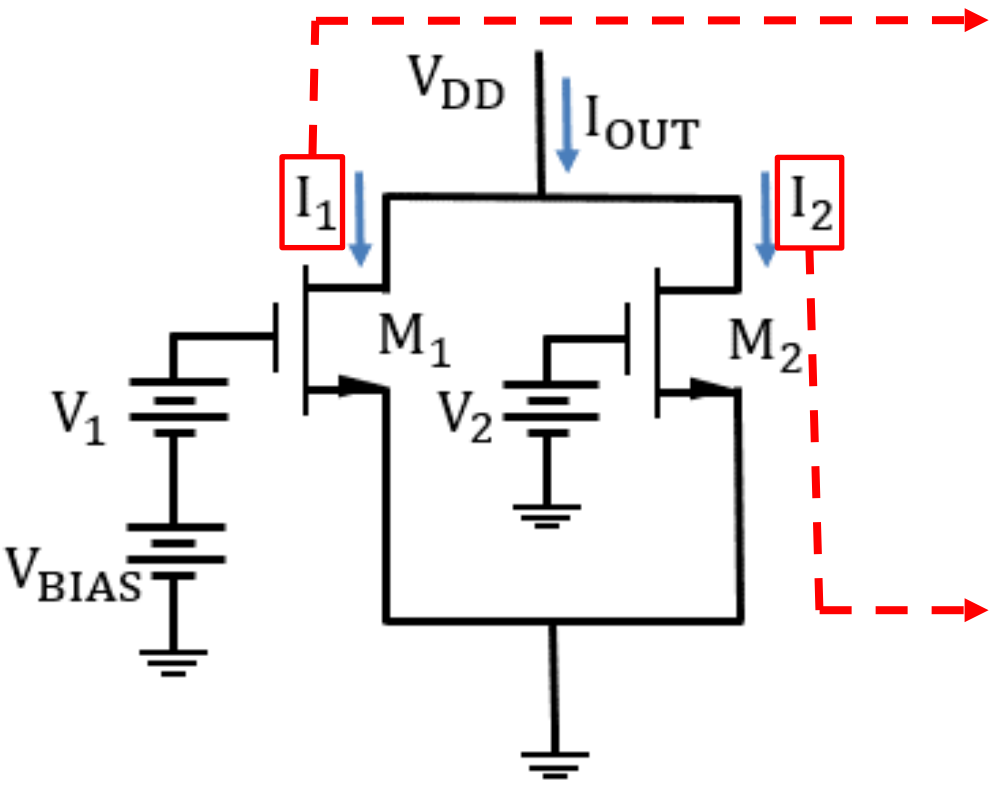


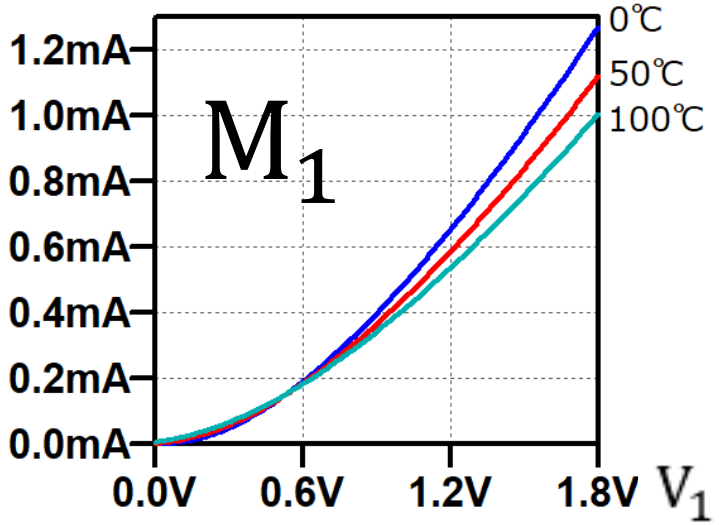
Proposed circuit concept

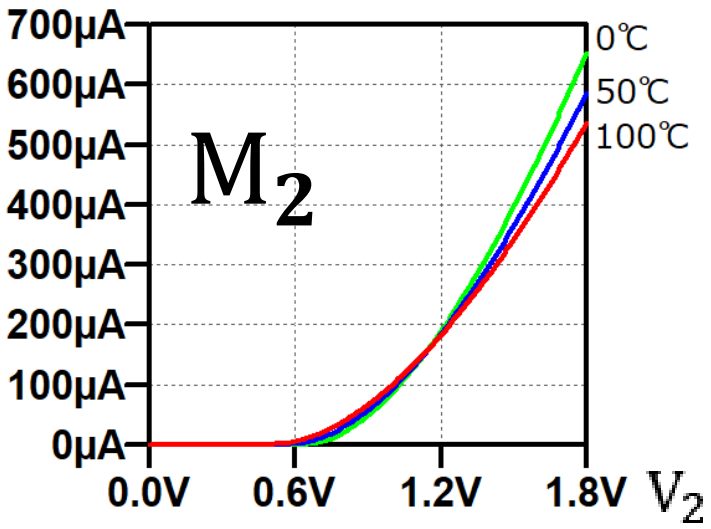
Simulation conditions

V_{BIAS}	0.6 V
V_1, V_2	0 ~ 1.8 V
V_{DD}	5.0 V
M_1, M_2	W=20 um, L=2.0 um

I_D-V_{GS} Characteristics of Two MOSFETs

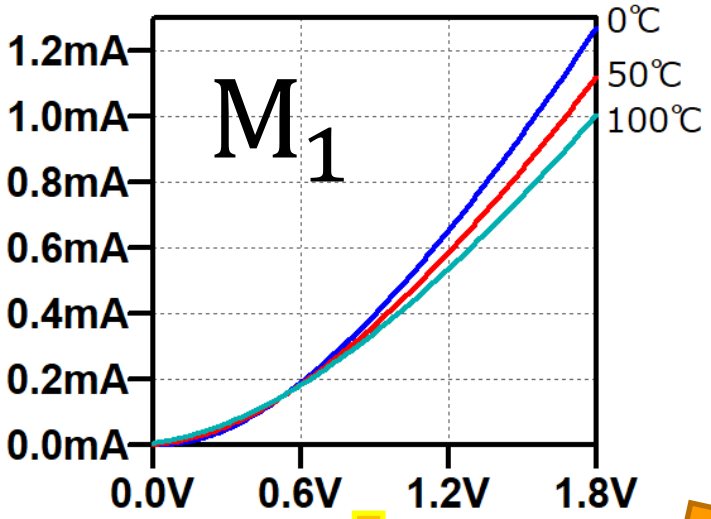


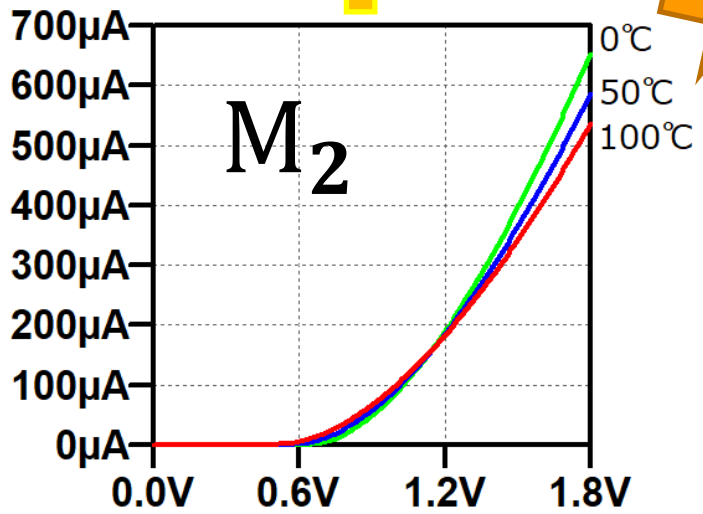


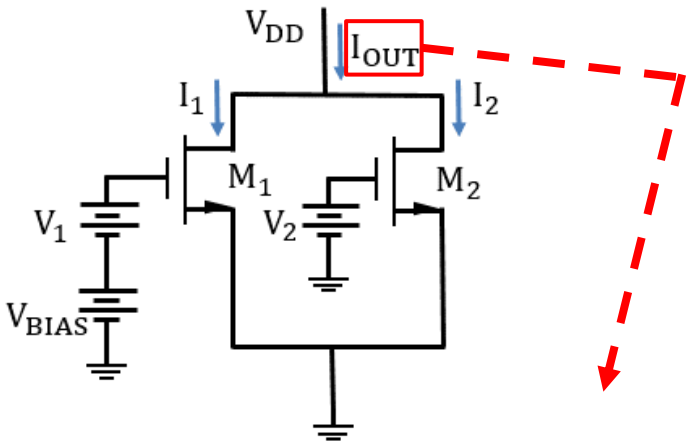


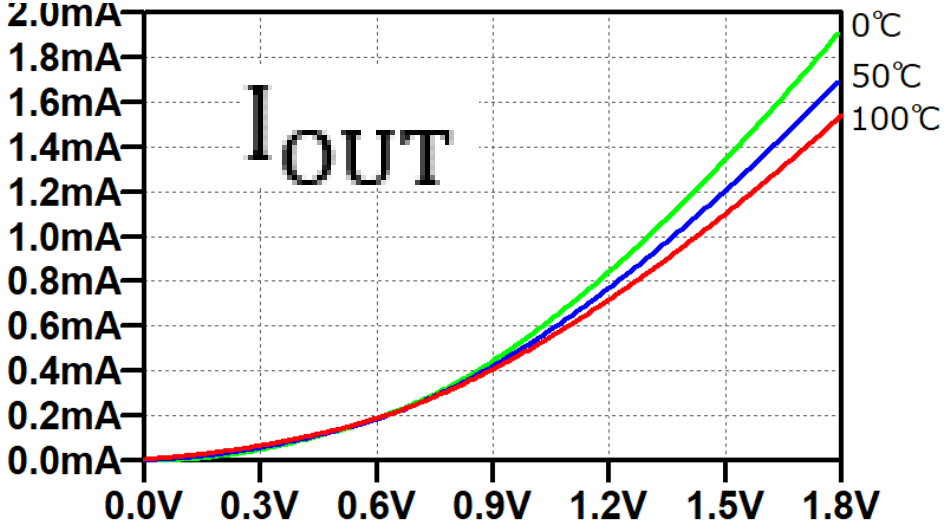
Temperature characteristics are shifted.

Cancellation of Temperature Characteristics









Output current I_{OUT}

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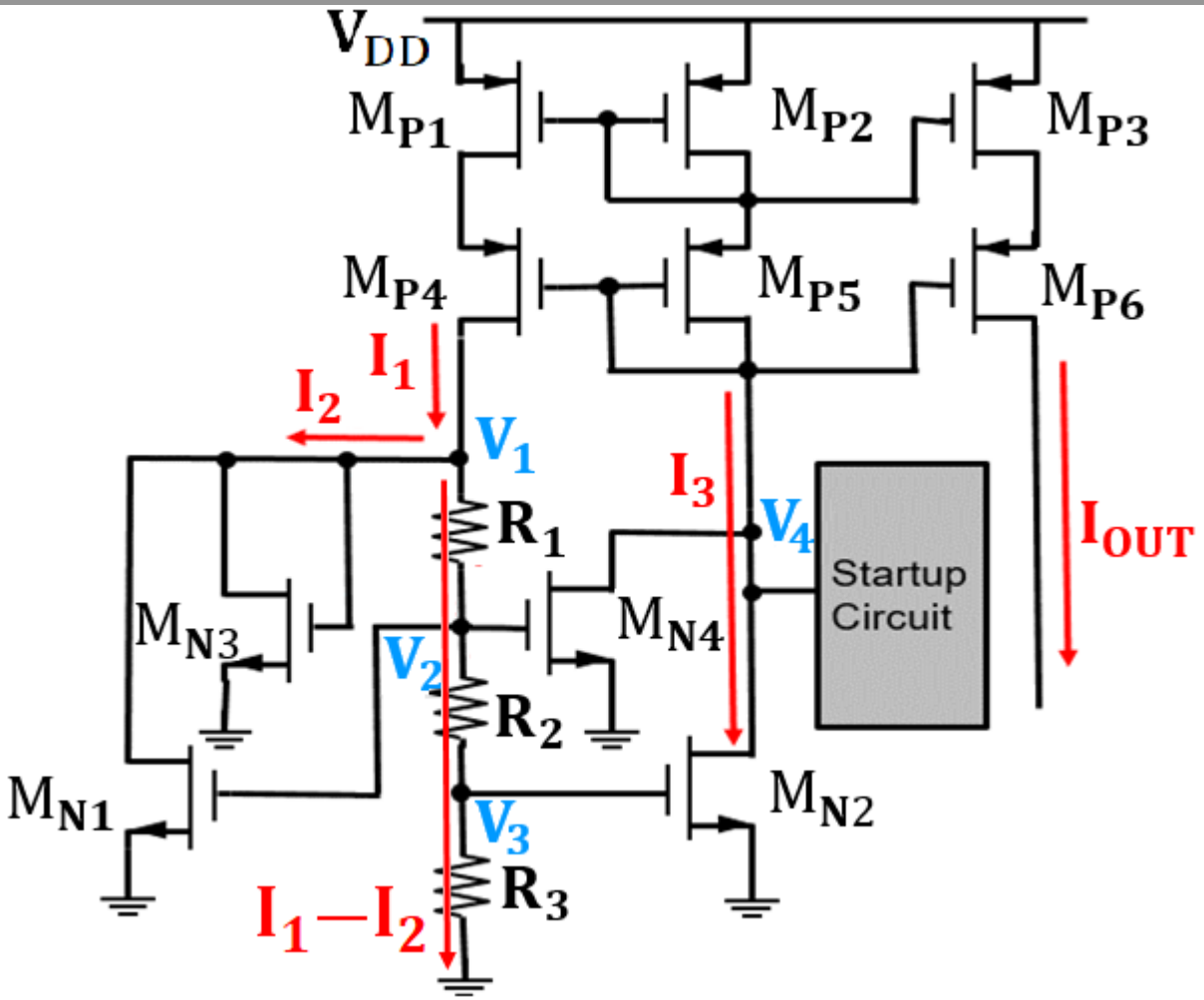
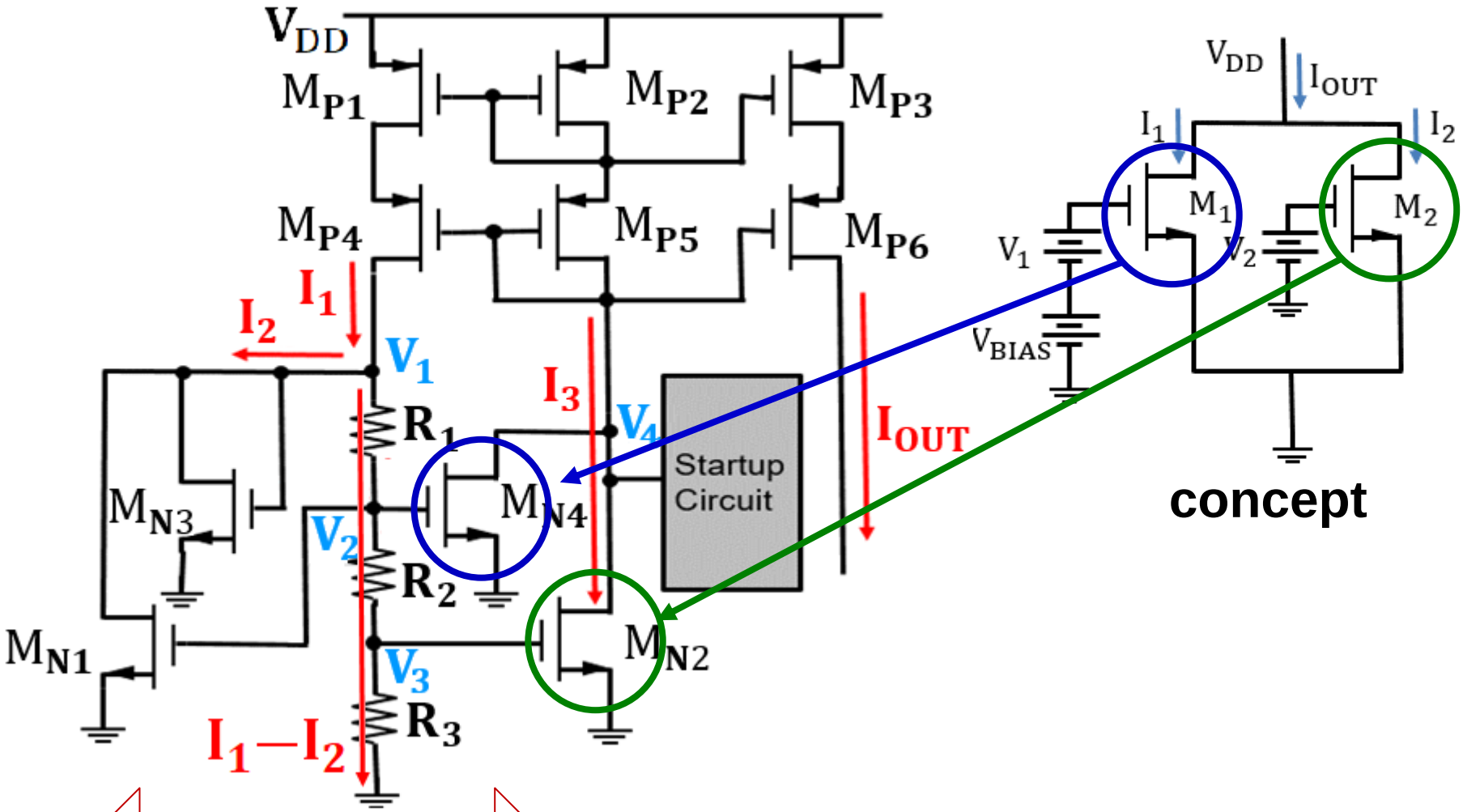
Proposed circuit

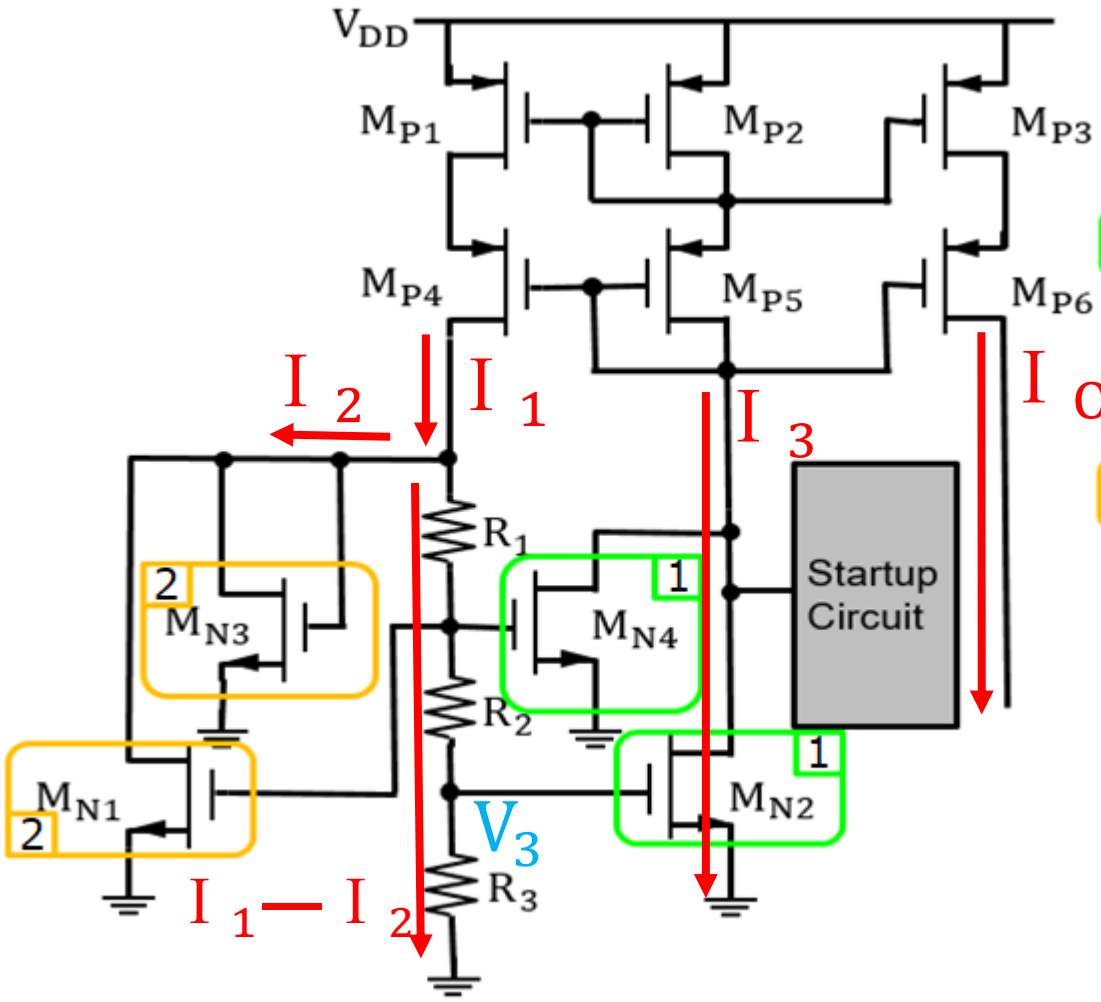


Proposed circuit using self-bias

Compared to the concept circuit



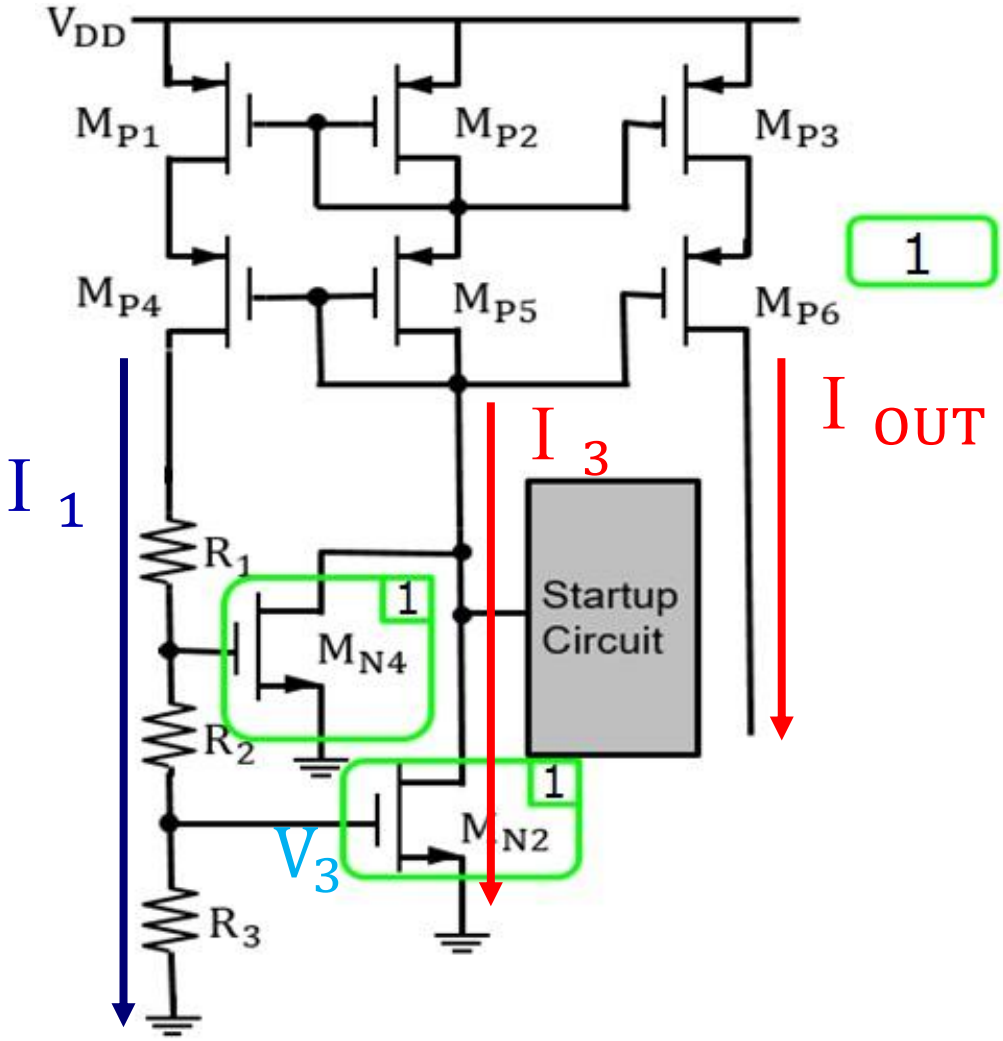
Negative Feedback for Self-Bias



1 **MOS for main current**

2 **MOS for negative feedback**

Self-Bias Problem

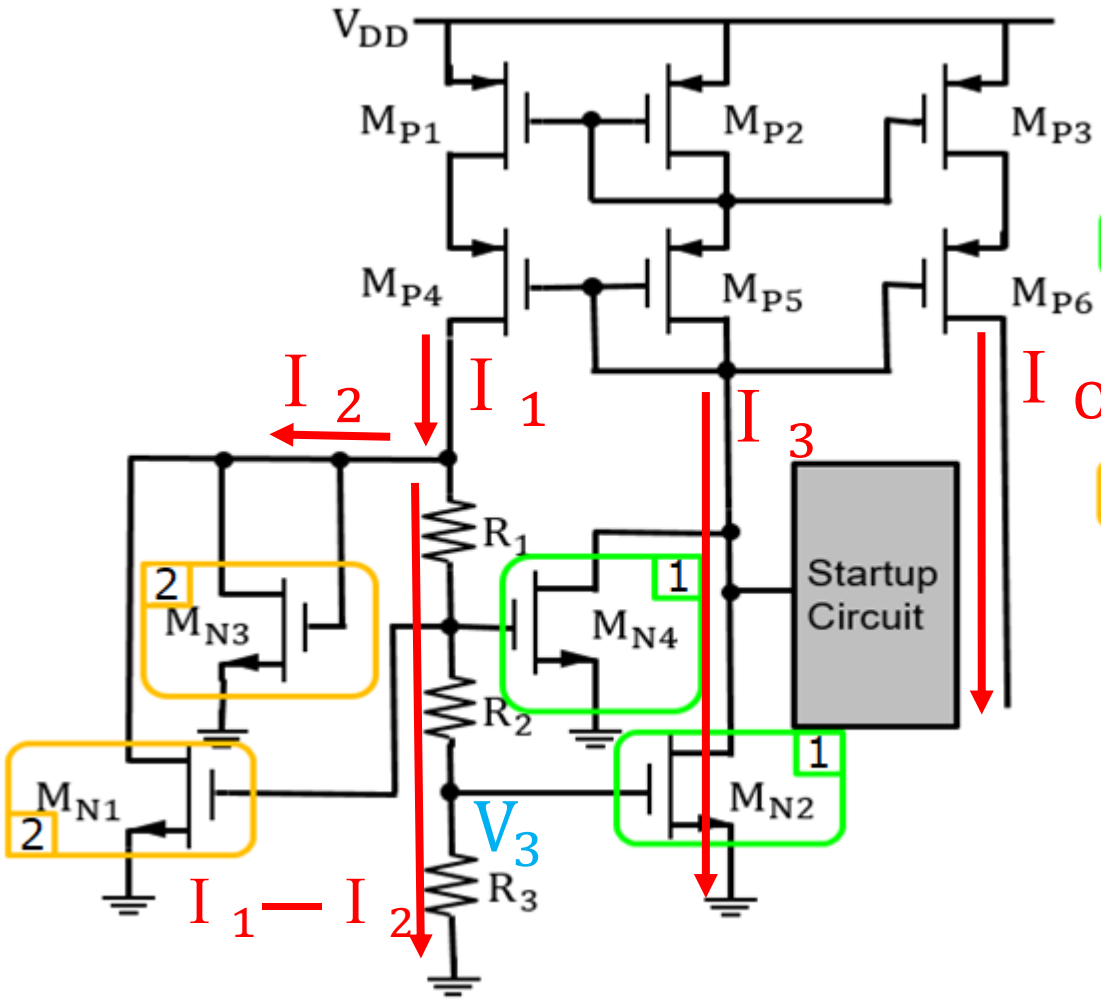


MOS for main current

I_1 increase
→ I_3 increase
→ I_1 increase
→ I_3 increase
⋮

Positive Feedback !

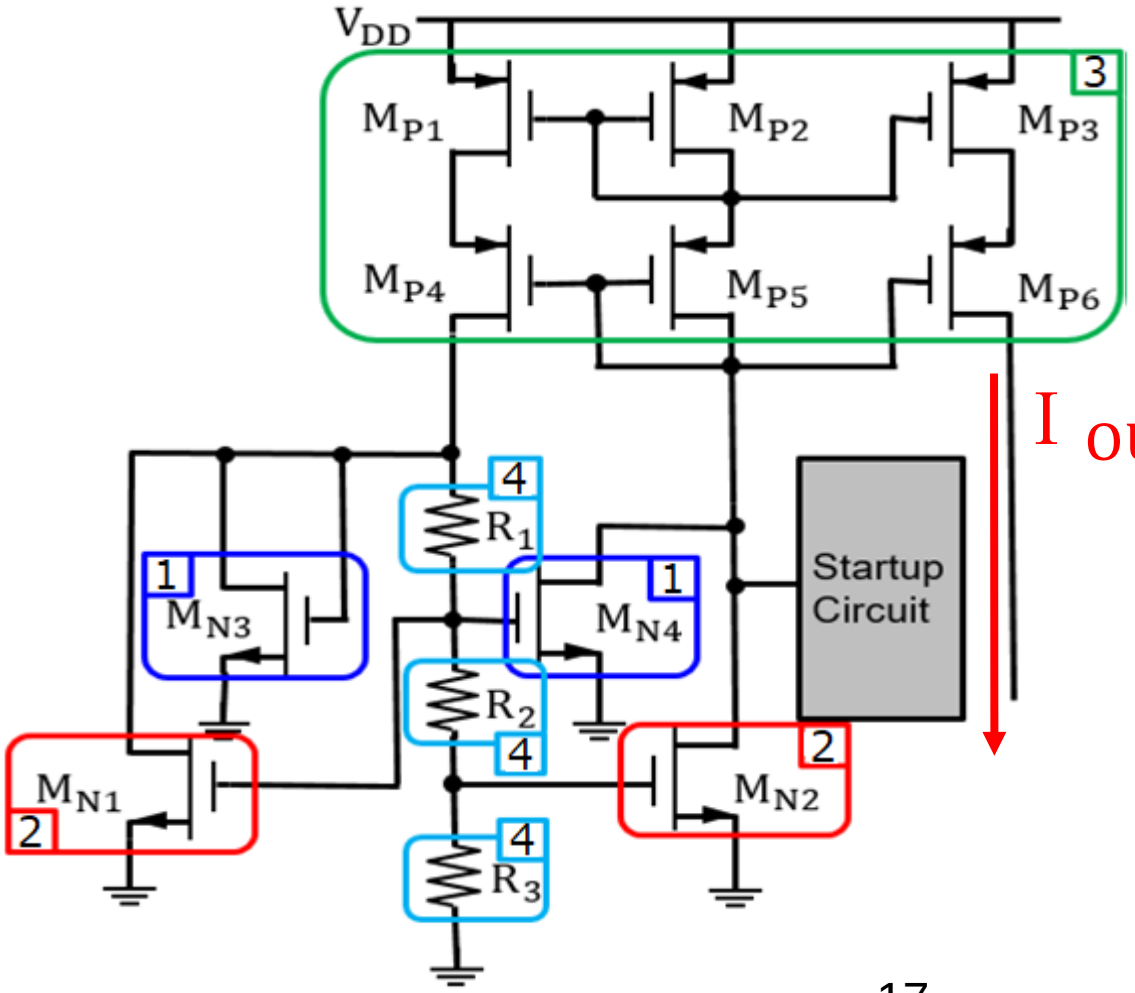
Negative Feedback for Self-Bias



1 **MOS for main current**

2 **MOS for negative feedback**

Roles of MOS FETs and Resistors



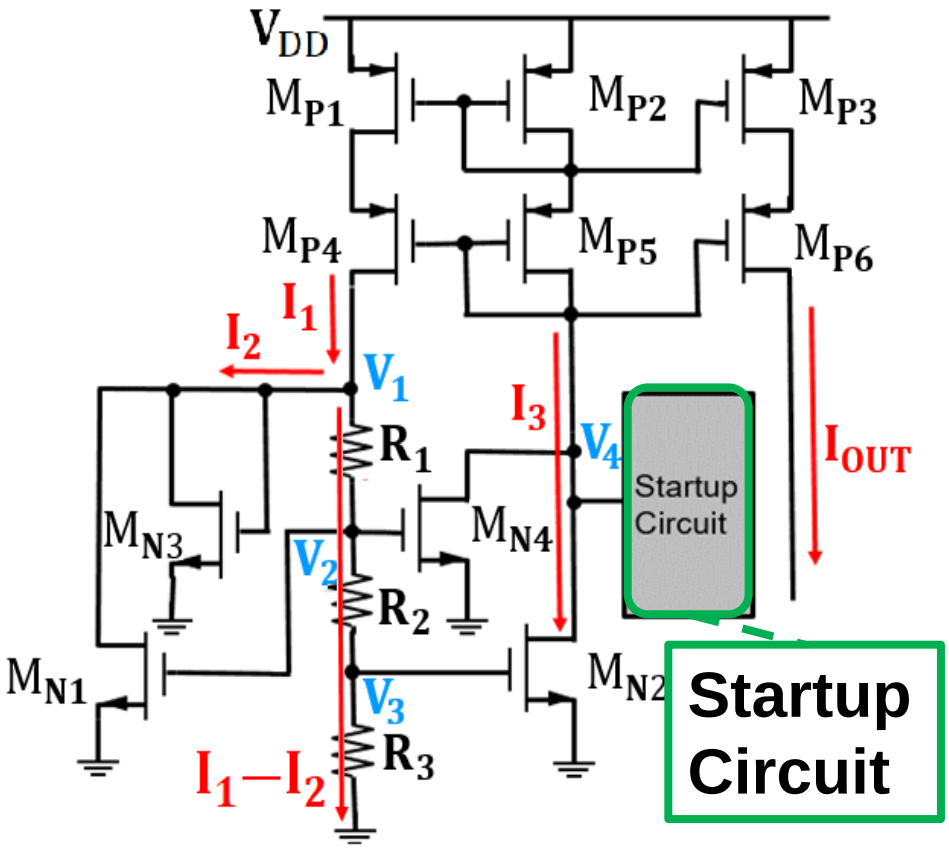
1 **Reference MOS**

2 **To cancel temperature effects**

3 **Cascode current mirror**

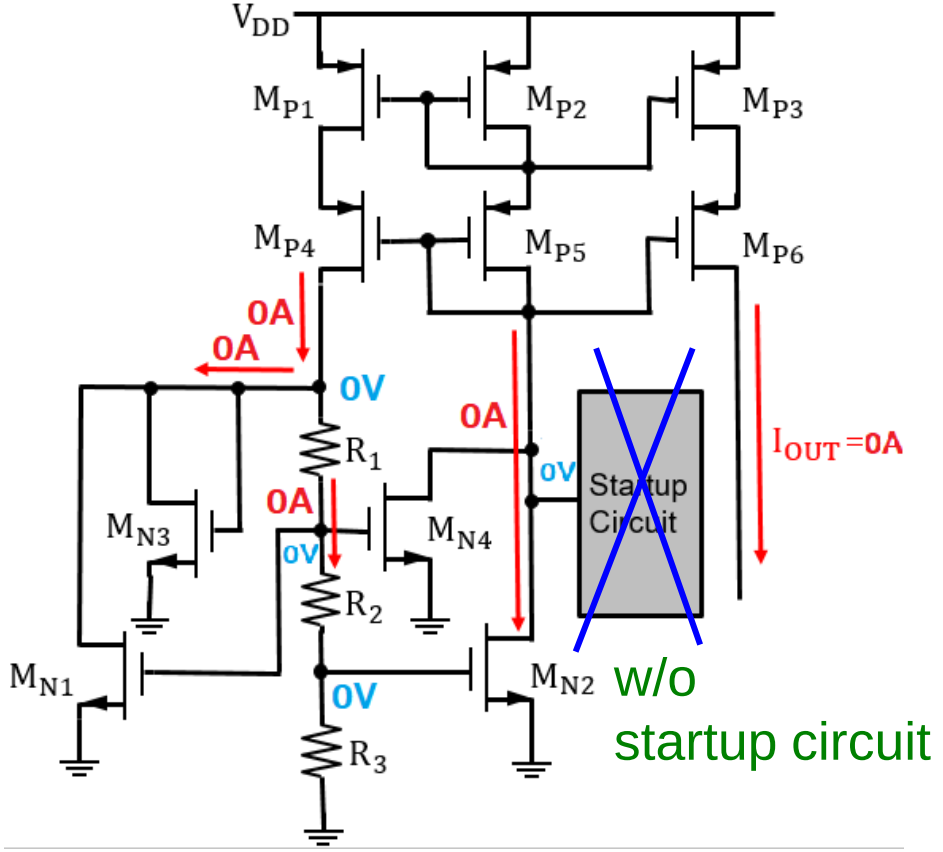
4 **Bias voltage setting resistors**

Startup Circuit is Needed



I_{OUT} conduction state

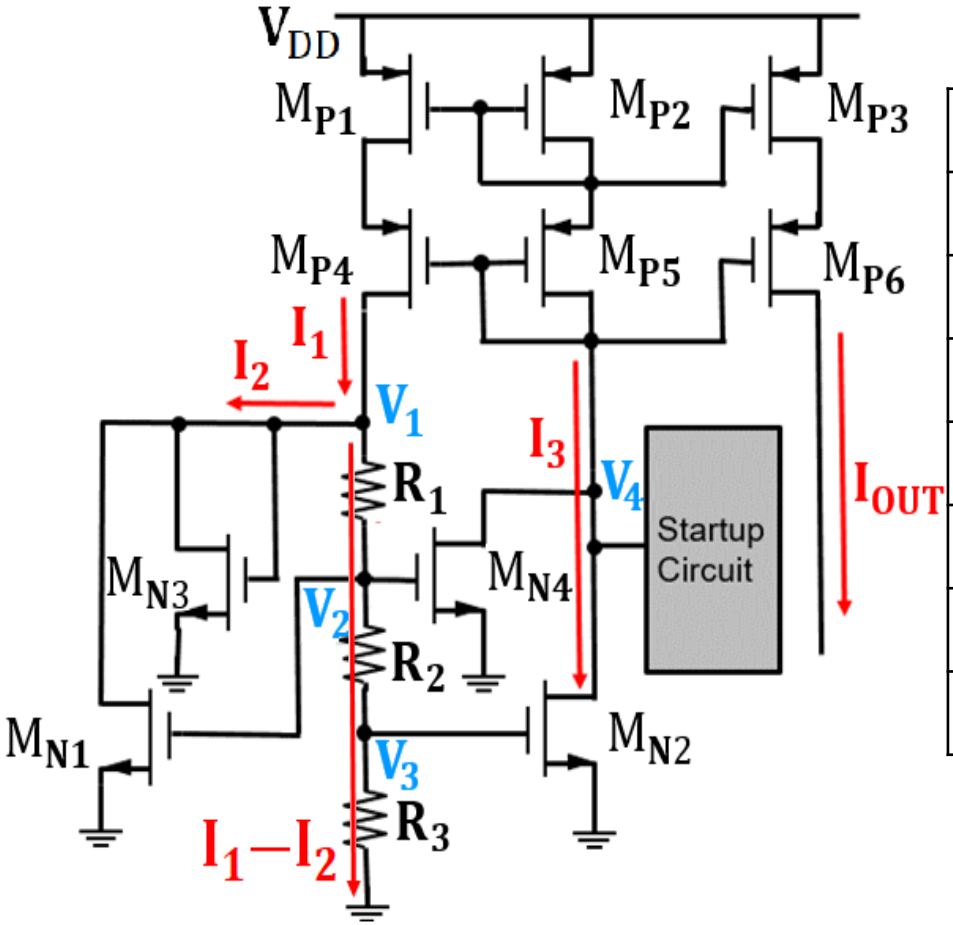
Proper operation



$I_{OUT} = 0$

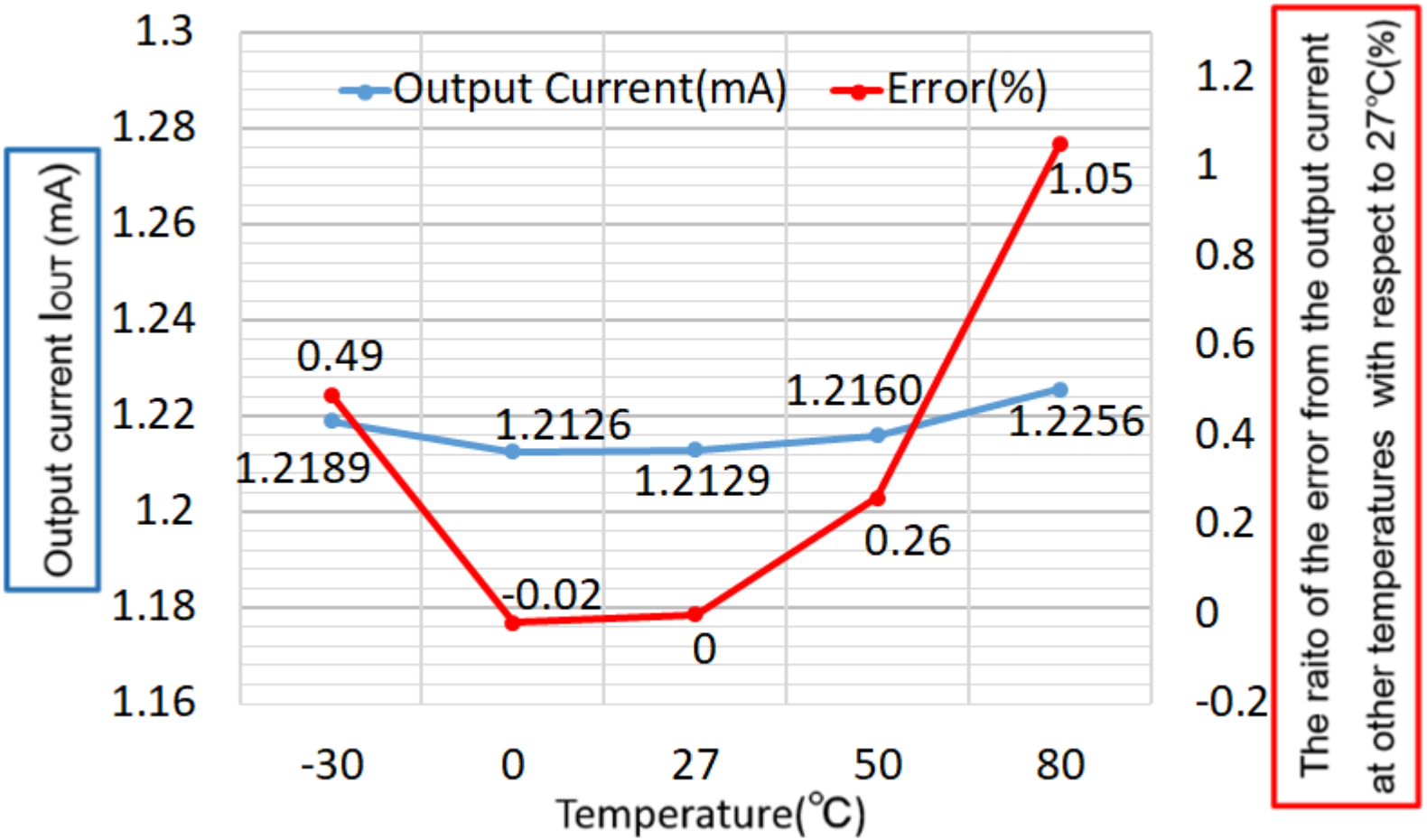
Malfunction

SPICE Simulation Conditions



$M_{P1} \sim M_{P6}$	W=800um,L=2.0um
M_{N1}, M_{N3}	W=0.25um,L=2.0um
M_{N2}	W=200um,L=2.0um
M_{N4}	W=20um, L=2.0um
R_1	5.0 kΩ
R_2	1.61 kΩ
R_3	1.5 kΩ
V_{DD}	5.0 V

Output Current I_{OUT} Deviation



Output current IOUT against temperature change from current @ 27 °C.

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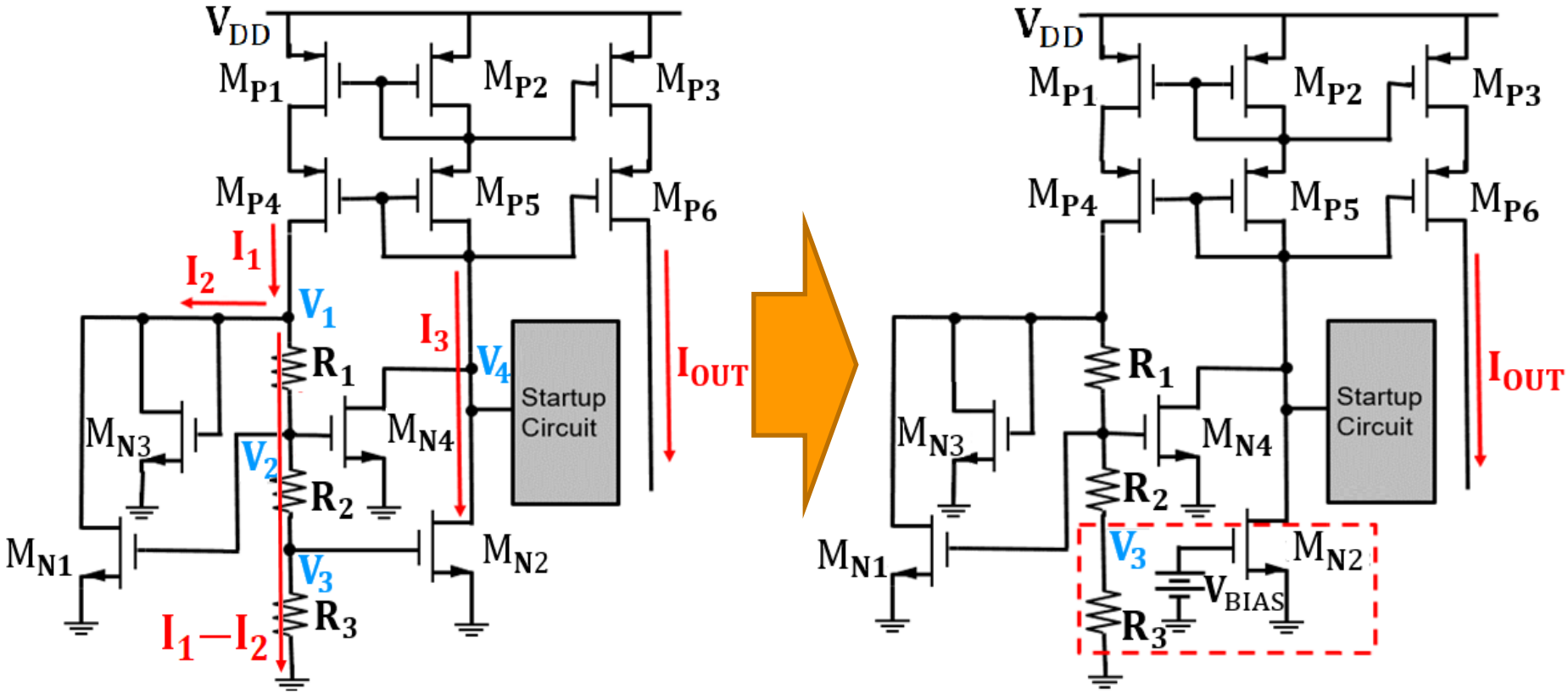
Feedback Loop Disconnection

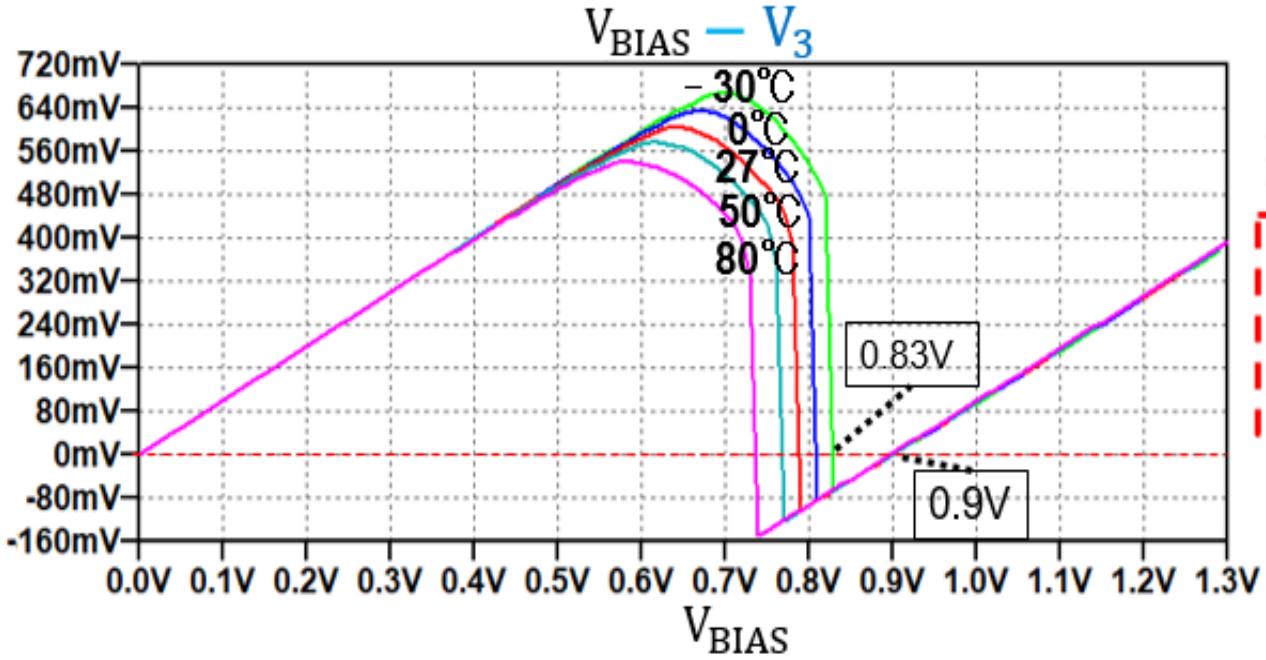


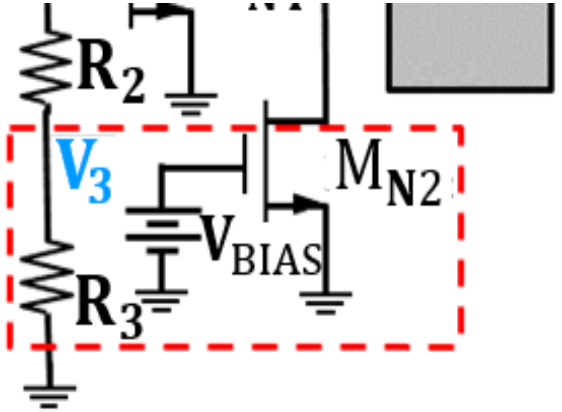
Disconnected loop at node V_3

&

Examine difference between V_{BIAS} and V_3 ($V_{BIAS} - V_3$)

Operation of Open-Loop Circuit



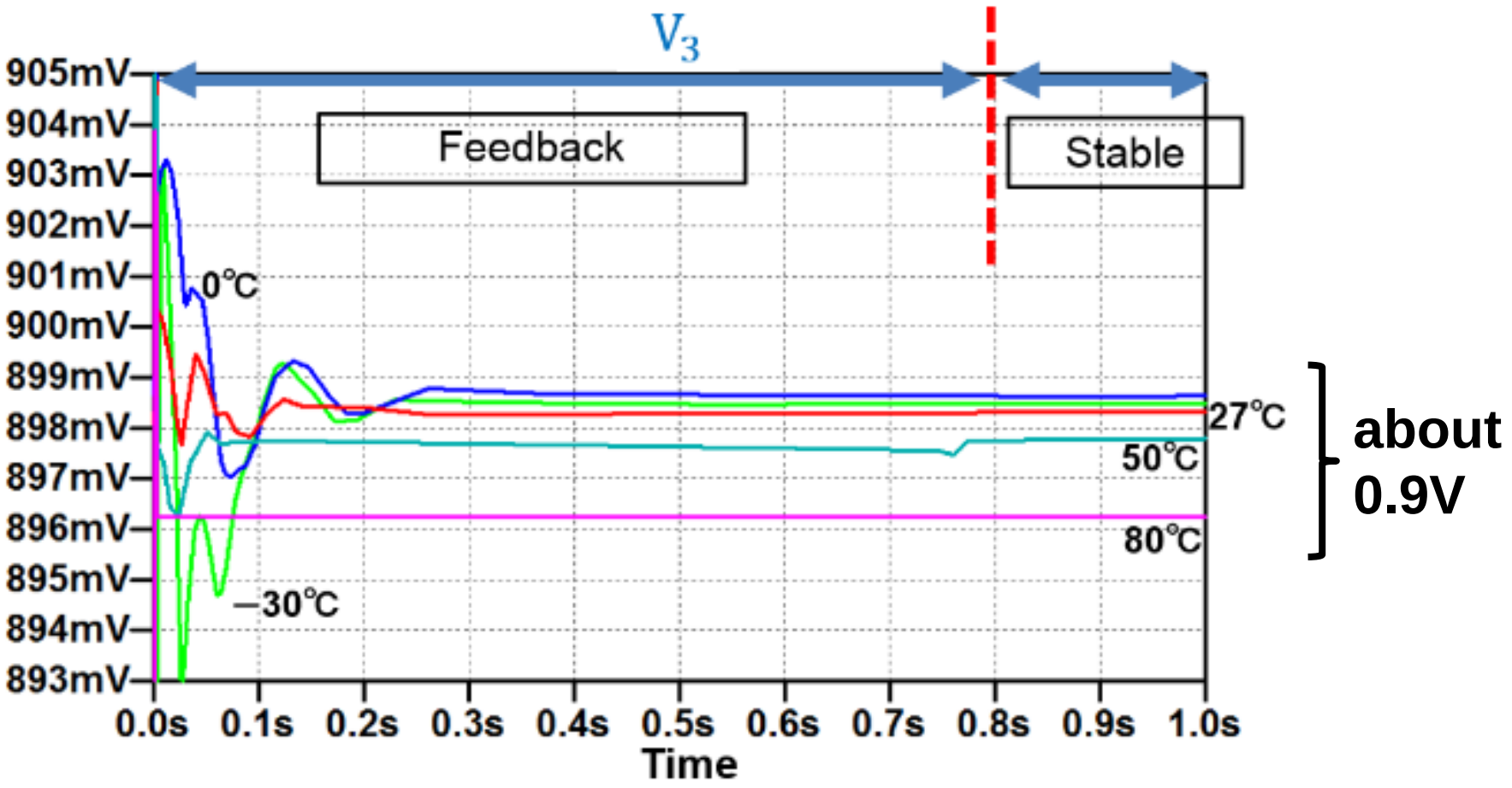


V_{BIAS} **vs. (**$V_{BIAS} - V_3$**) characteristics of the open-loop circuit**

VBIAS < V3 : V_3 **raises** M_{N2} **gate voltage**

VBIAS > V3 : V_3 **lowers** M_{N2} **gate voltage**

Negative Feedback Operation



Simulated Negative Feedback Process of V_3

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Conclusion

- **We have proposed temperature-insensitive MOS current source.**
- **Self-bias and startup circuits are used.**
- **Temperature-insensitivity is verified.**
- **Stability is analyzed and verified.**

Remaining work

- **Supply voltage insensitivity confirmation**