CMOS Thyristor Based Low Frequency Ring Oscillator

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Outline

- Overview of Ring Oscillators
- Simple Inverter Chain
- Current Starved Inverter Chain
- CMOS Thyristor Based Inverter
- CMOS Thyristor with Footer
- Comparison
  - Voltage Sensitivity
  - Temperature Sensitivity
- References

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Overview of Ring Oscillators

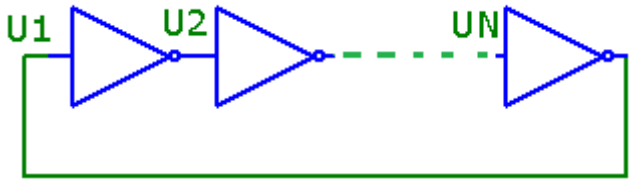
- **Design of Ring Oscillators**
  - Typically odd number of inverters
  - Used as delay cells
  - connected in cascade & in a closed loop

- **Oscillation frequency** given by:

$$f = \frac{1}{2N\tau_d}$$

Where, N → *is the No. of delay cells.*

τ_d → *is the delay time in each cell.*



AIM: Design Oscillator with Frequency = 1 kHz.
Vdd = 1.2 volts.

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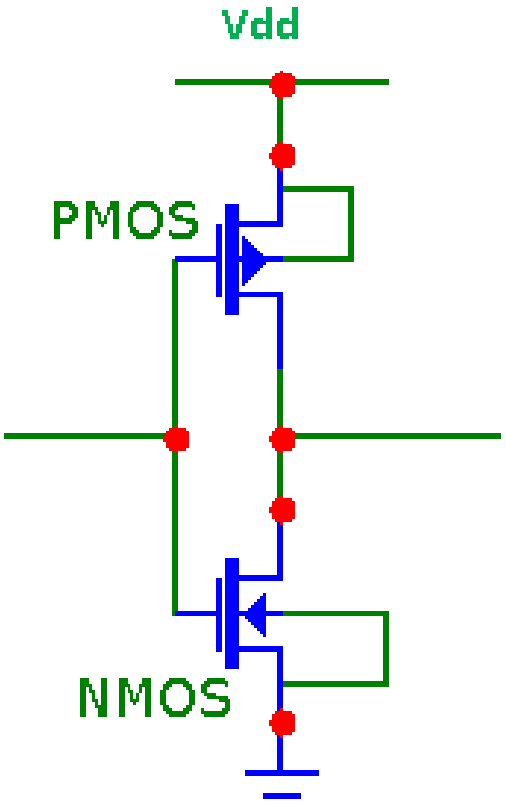
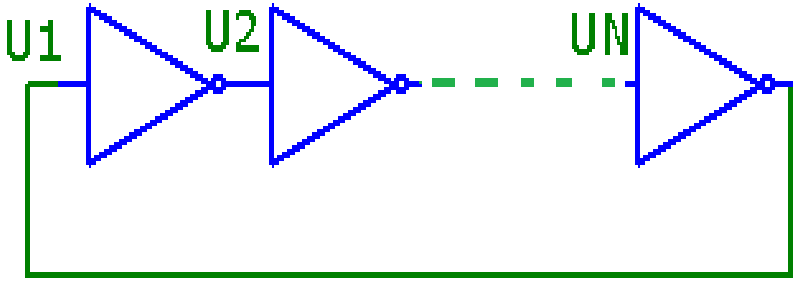
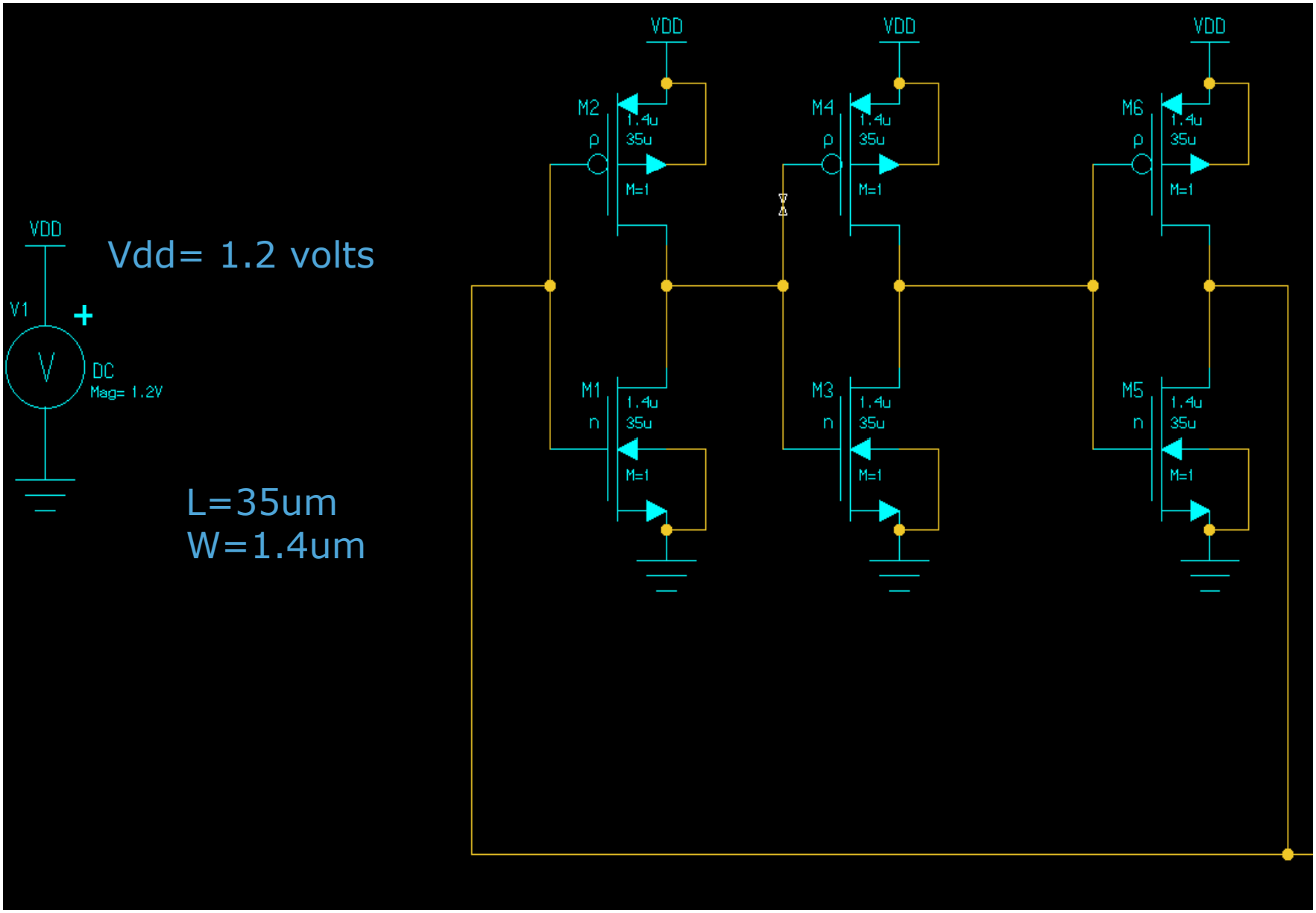
Simple Inverter Chain

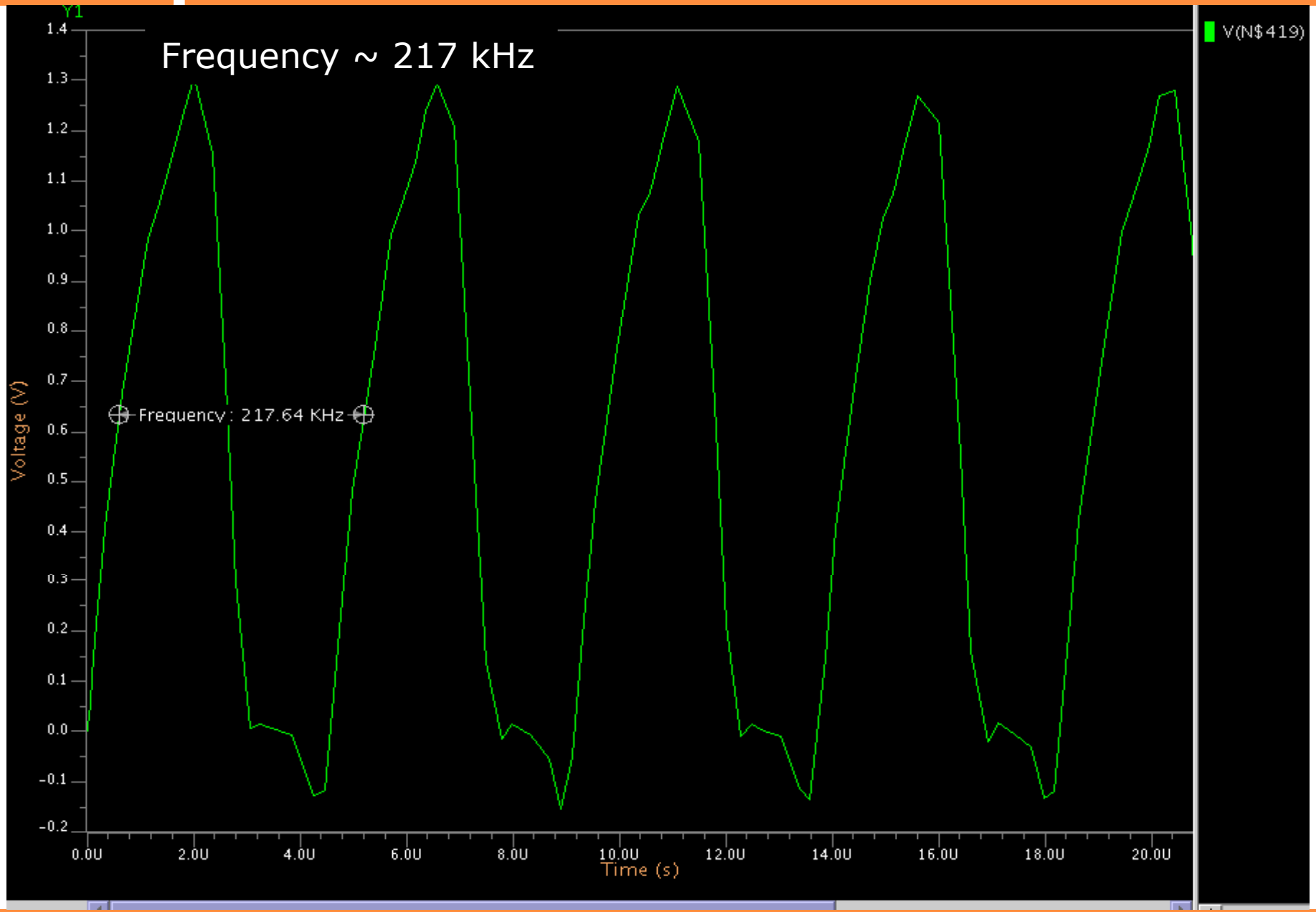




Simple Inverter Chain



Simple Inverter Chain



Simple Inverter Chain

- **To Achieve Frequency = 1 kHz**
  - No. of Inverters = 601
  - L = 35um
  - W = 1.4um
  - **Power Consumption = 716 nW**

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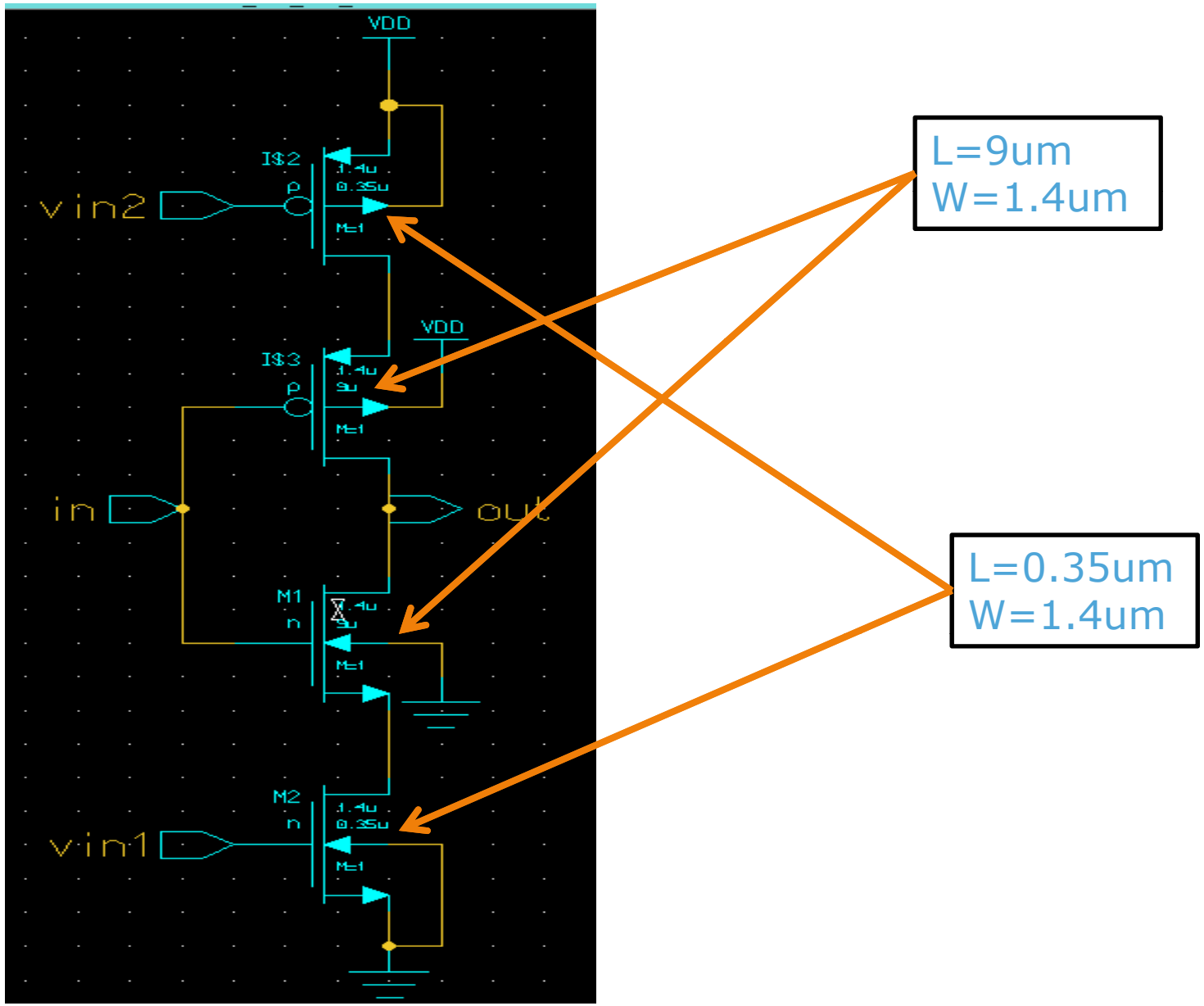
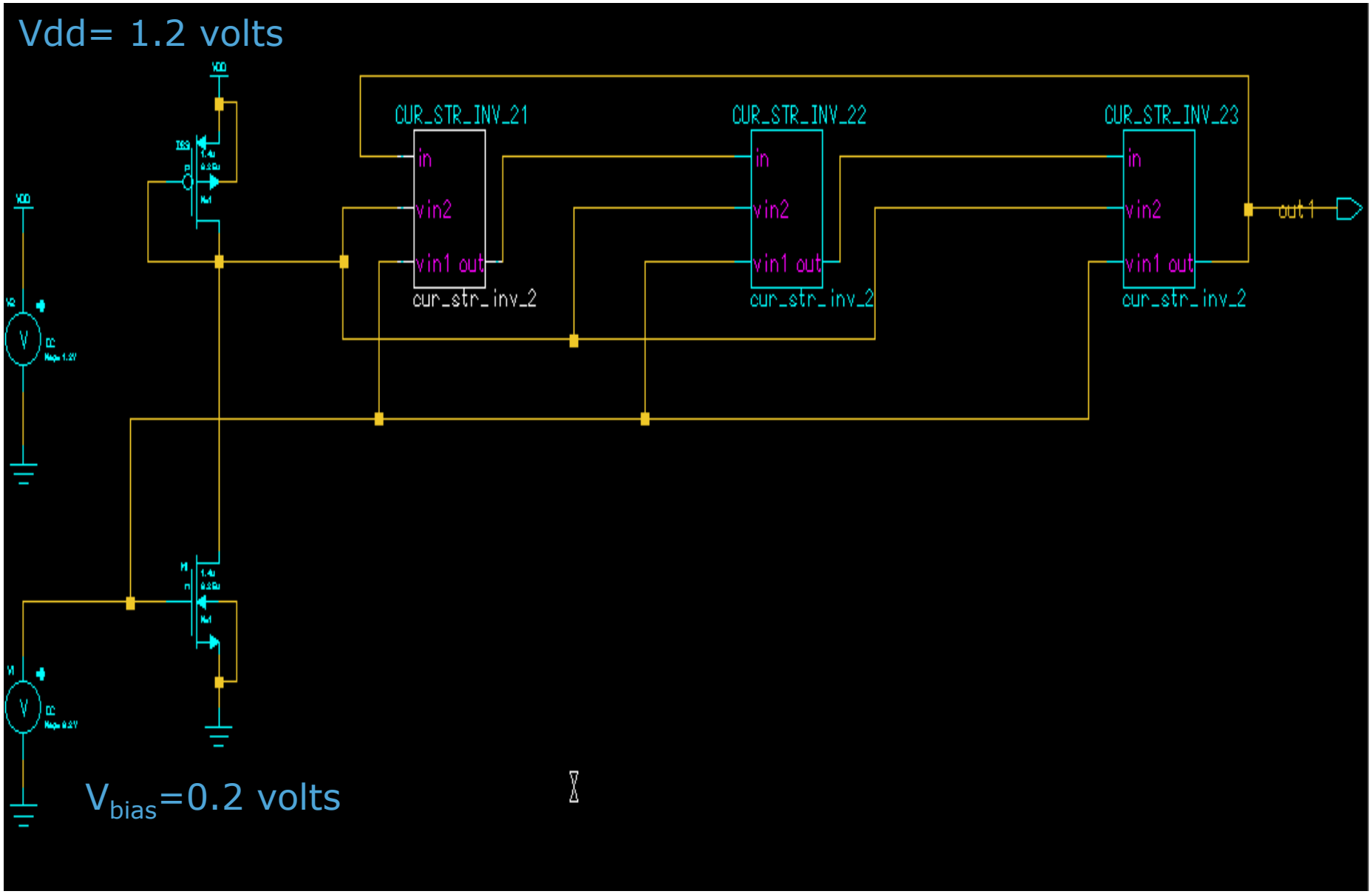
Current Starved Inverter Chain



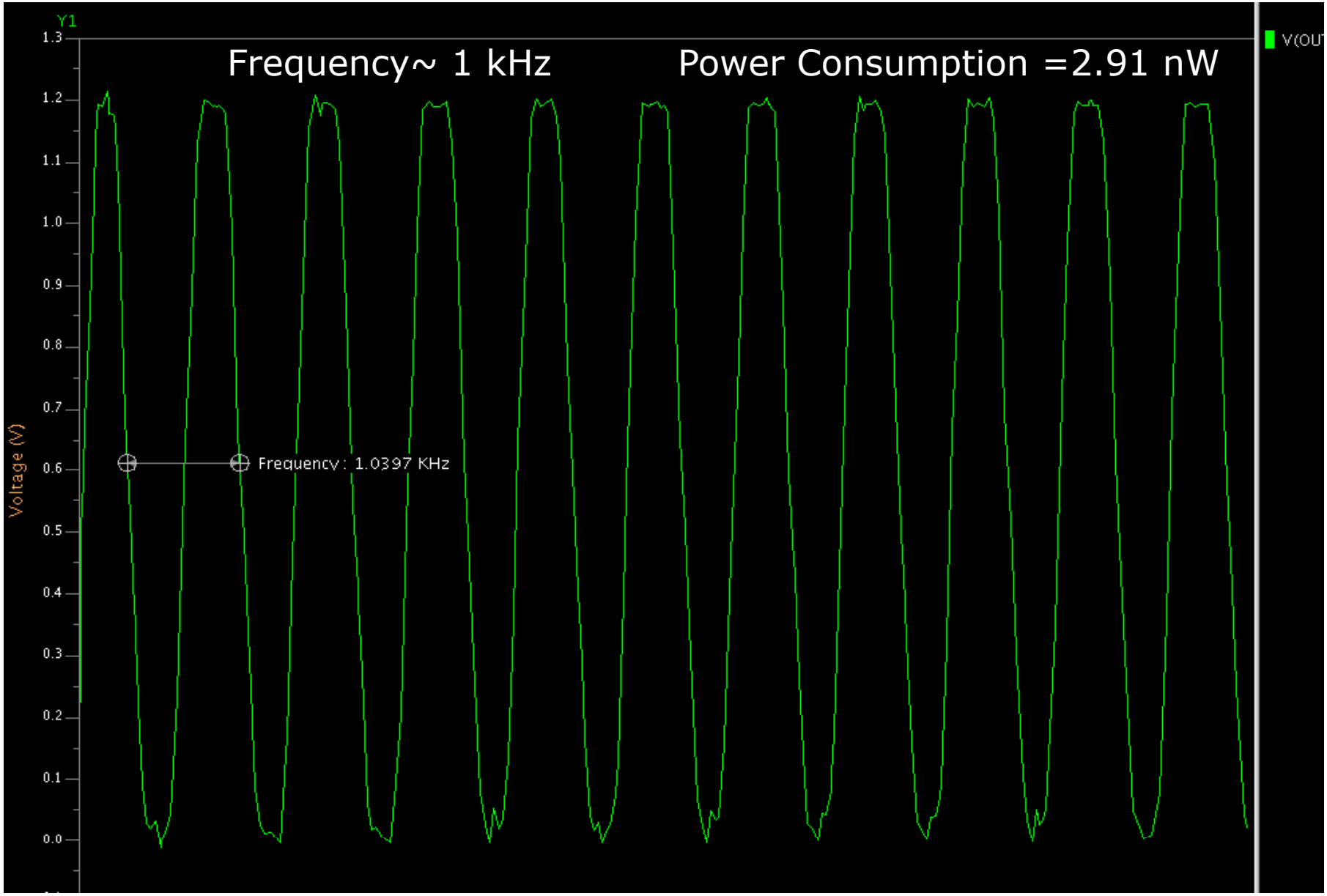
L=9um
W=1.4um

L=0.35um
W=1.4um

Current Starved Inverter Chain



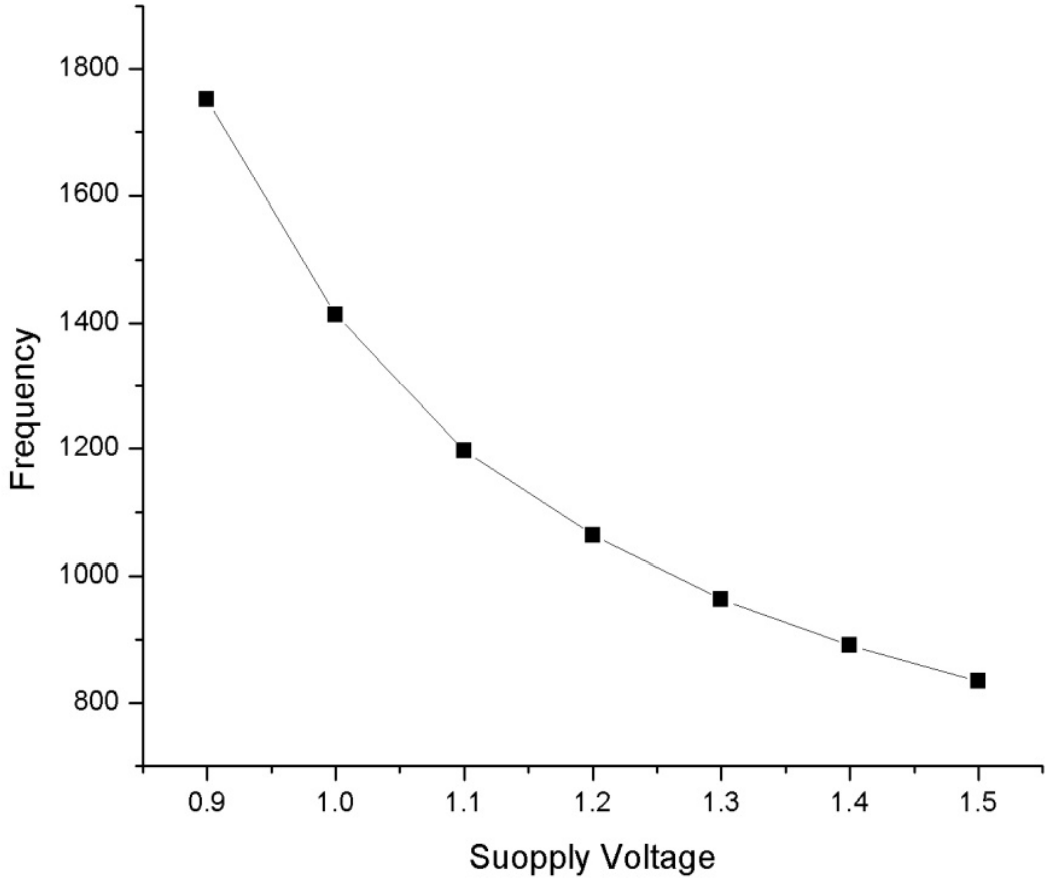
Current Starved Inverter Chain



Current Starved Inverter Chain

Issue

- Voltage Sensitivity



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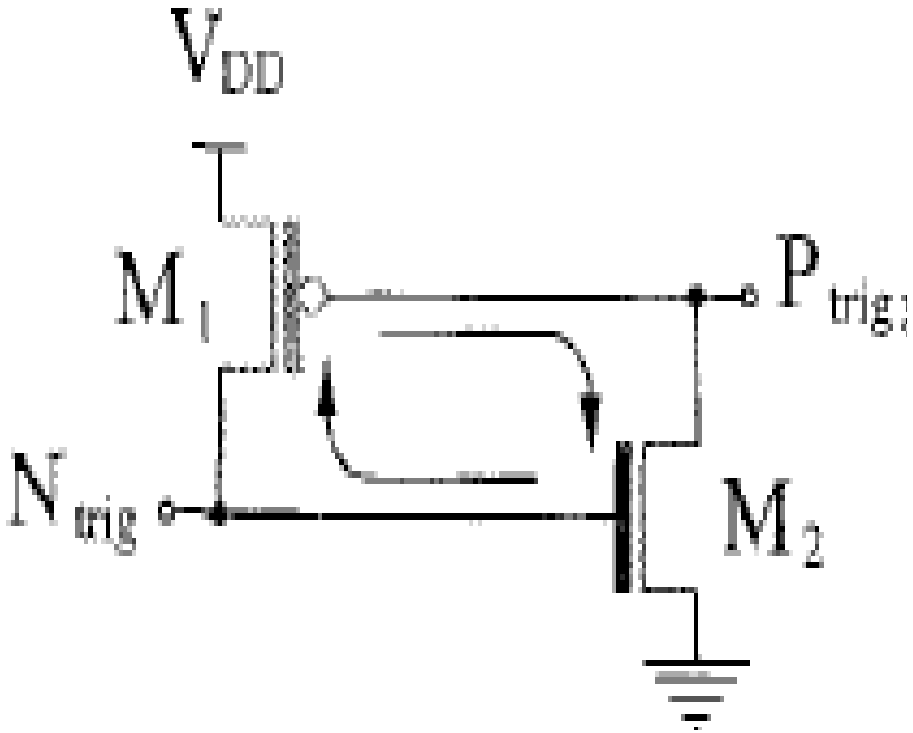
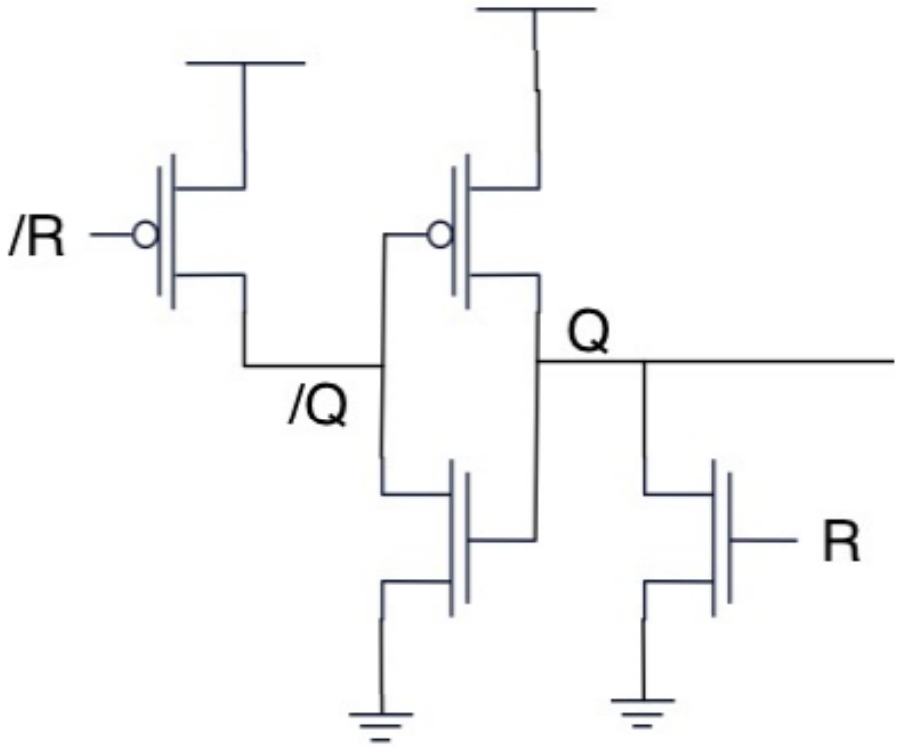
CMOS Thyristor Based Inverter

- Meta Stable Circuit
- Depend only on Leakage Current



CMOS Thyristor Based Inverter



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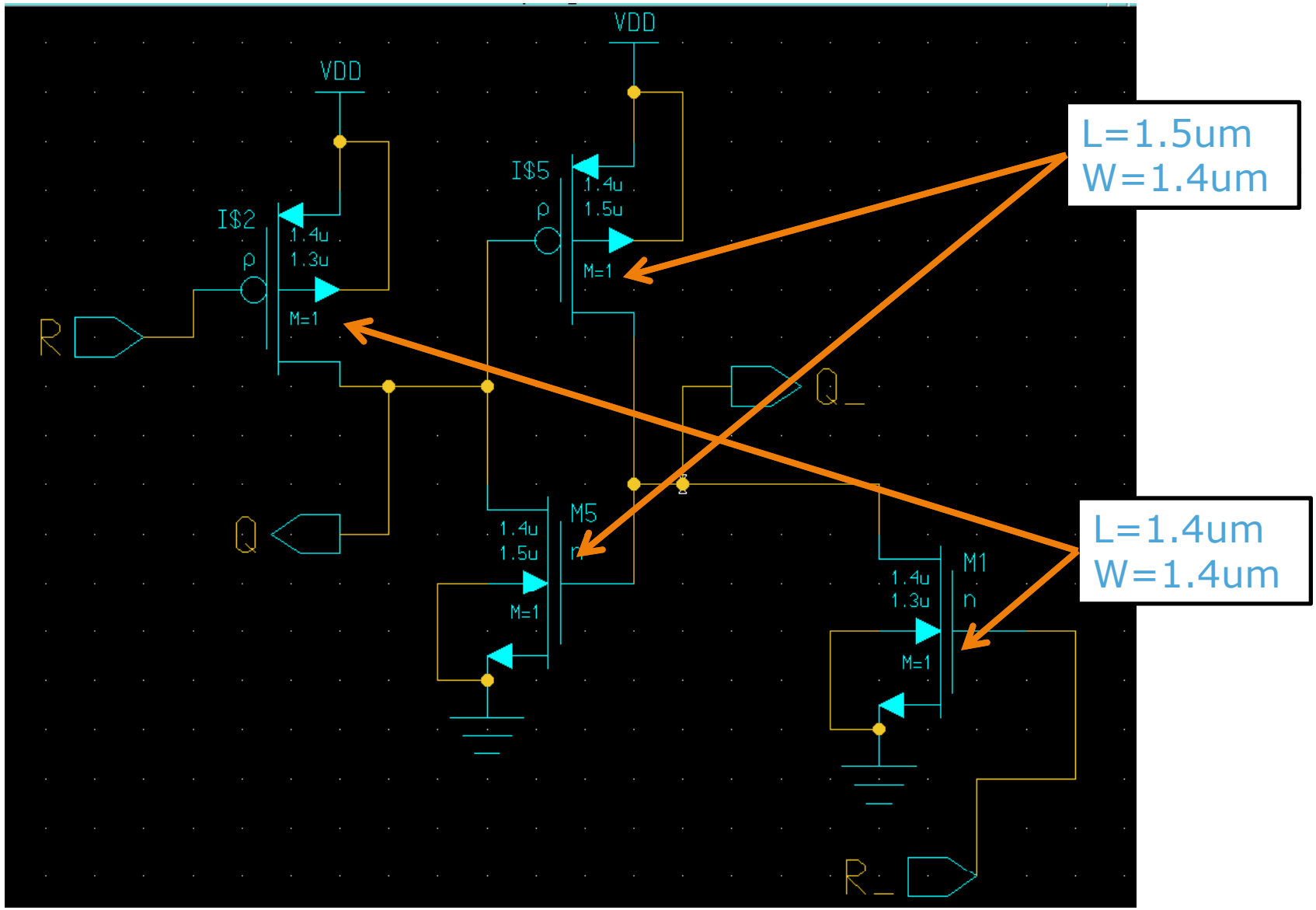
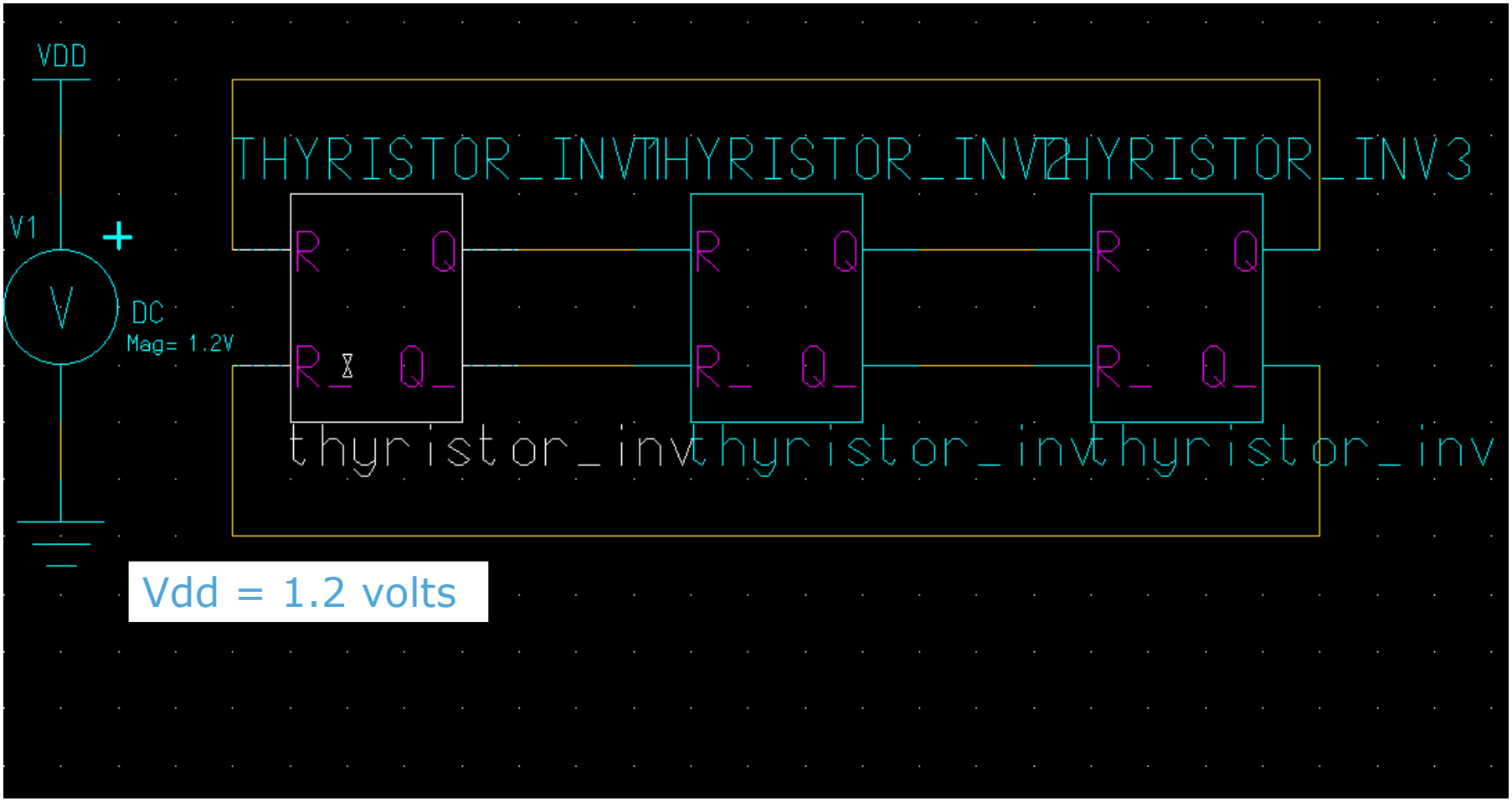
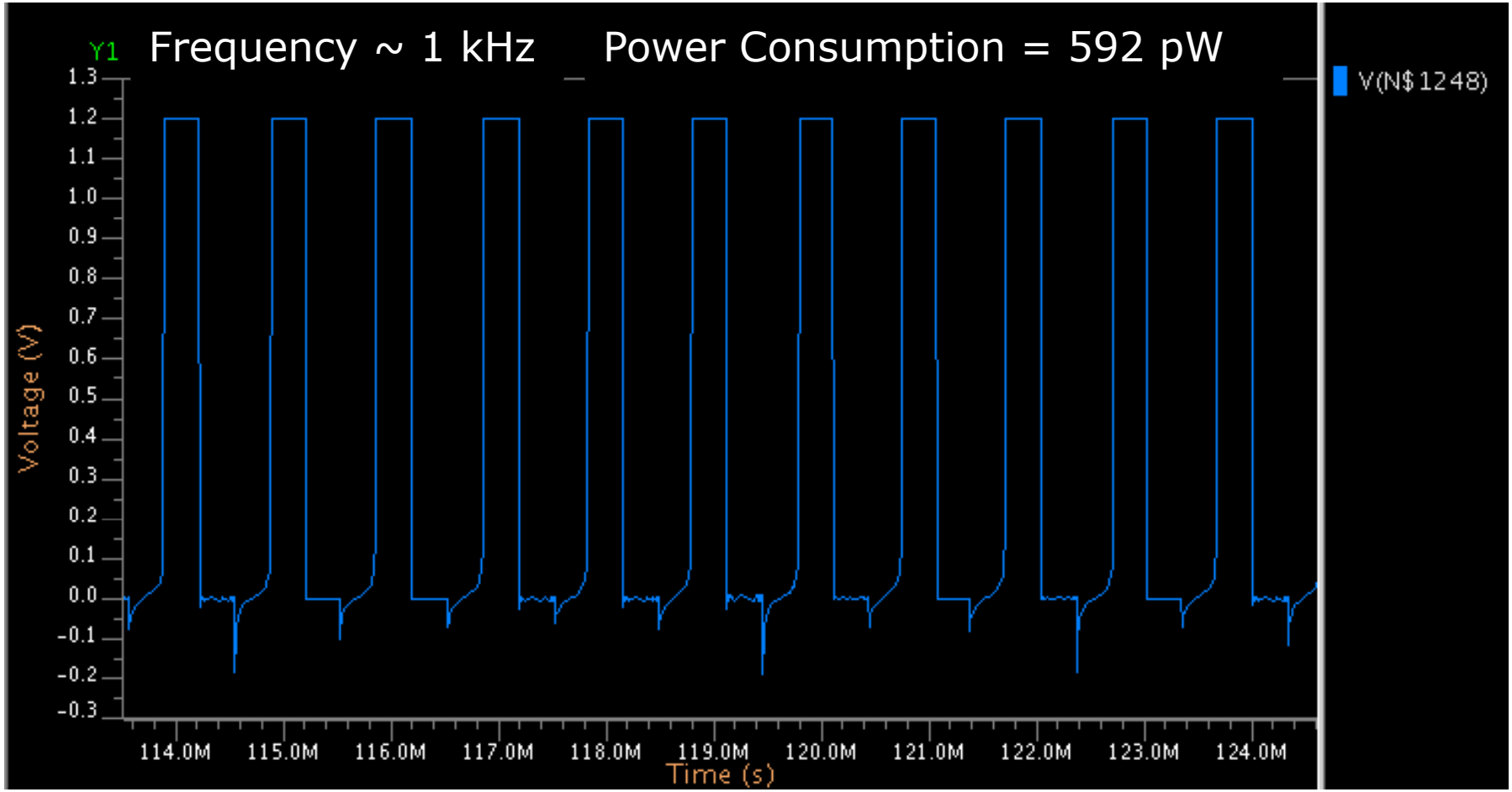


CMOS Thyristor Based Inverter



CMOS Thyristor Based Inverter



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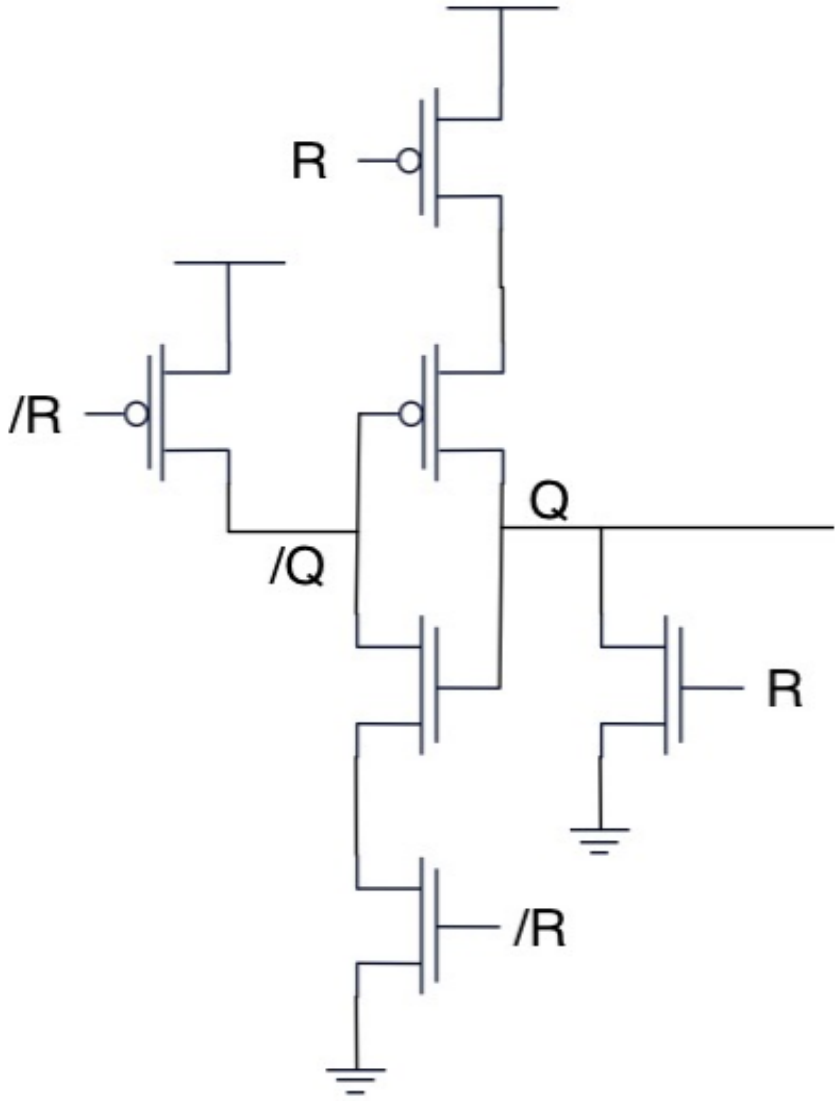
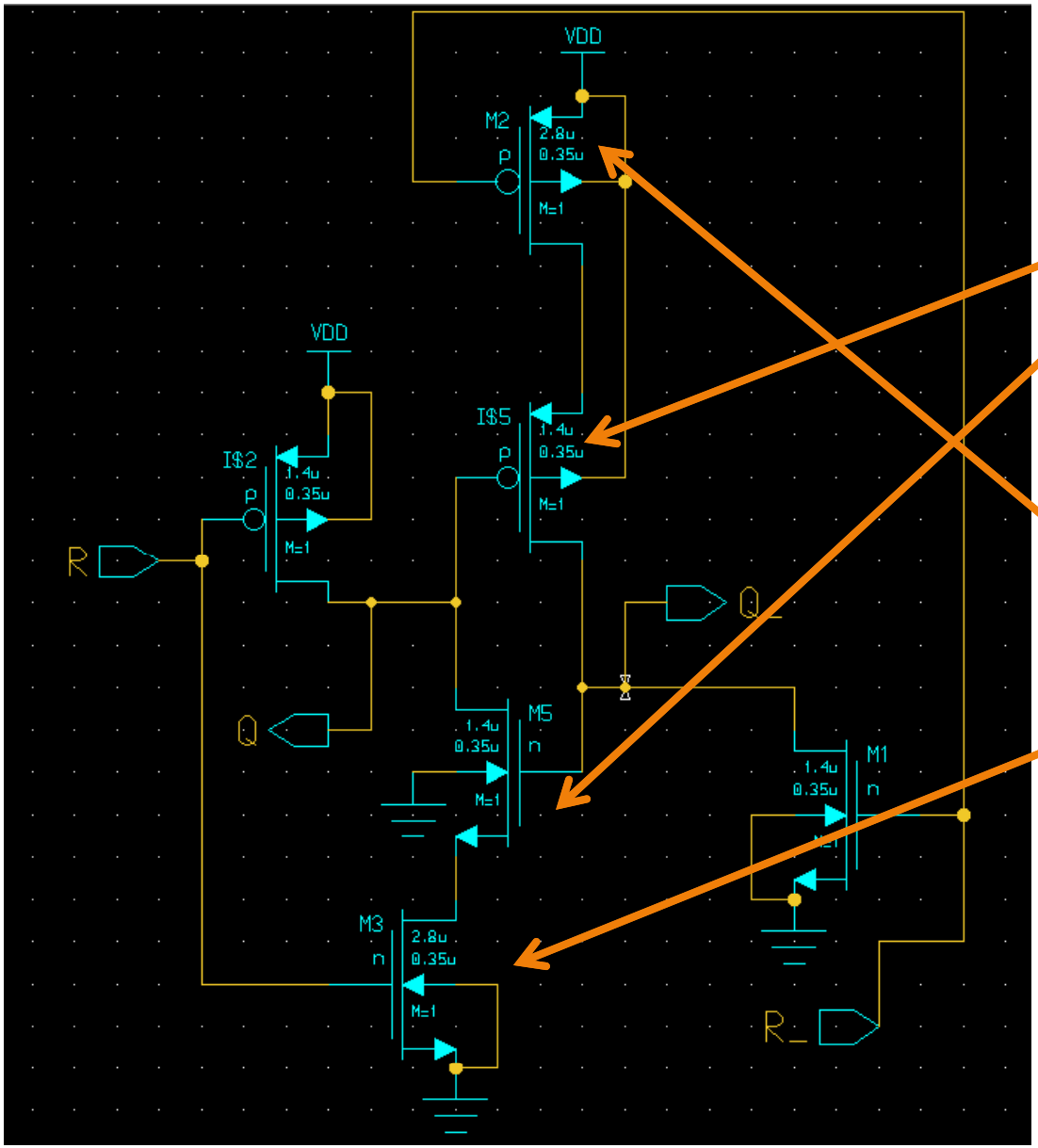
CMOS Thyristor with Footer



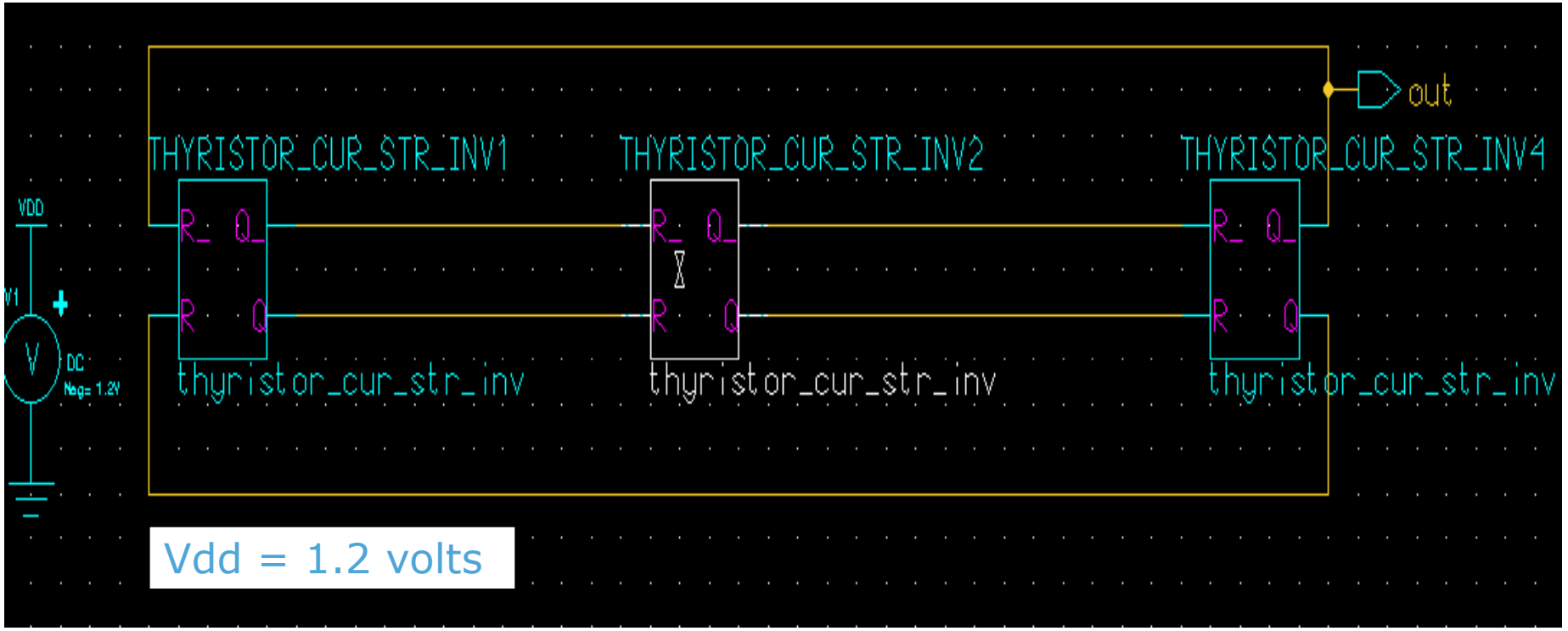
CMOS Thyristor with Footer



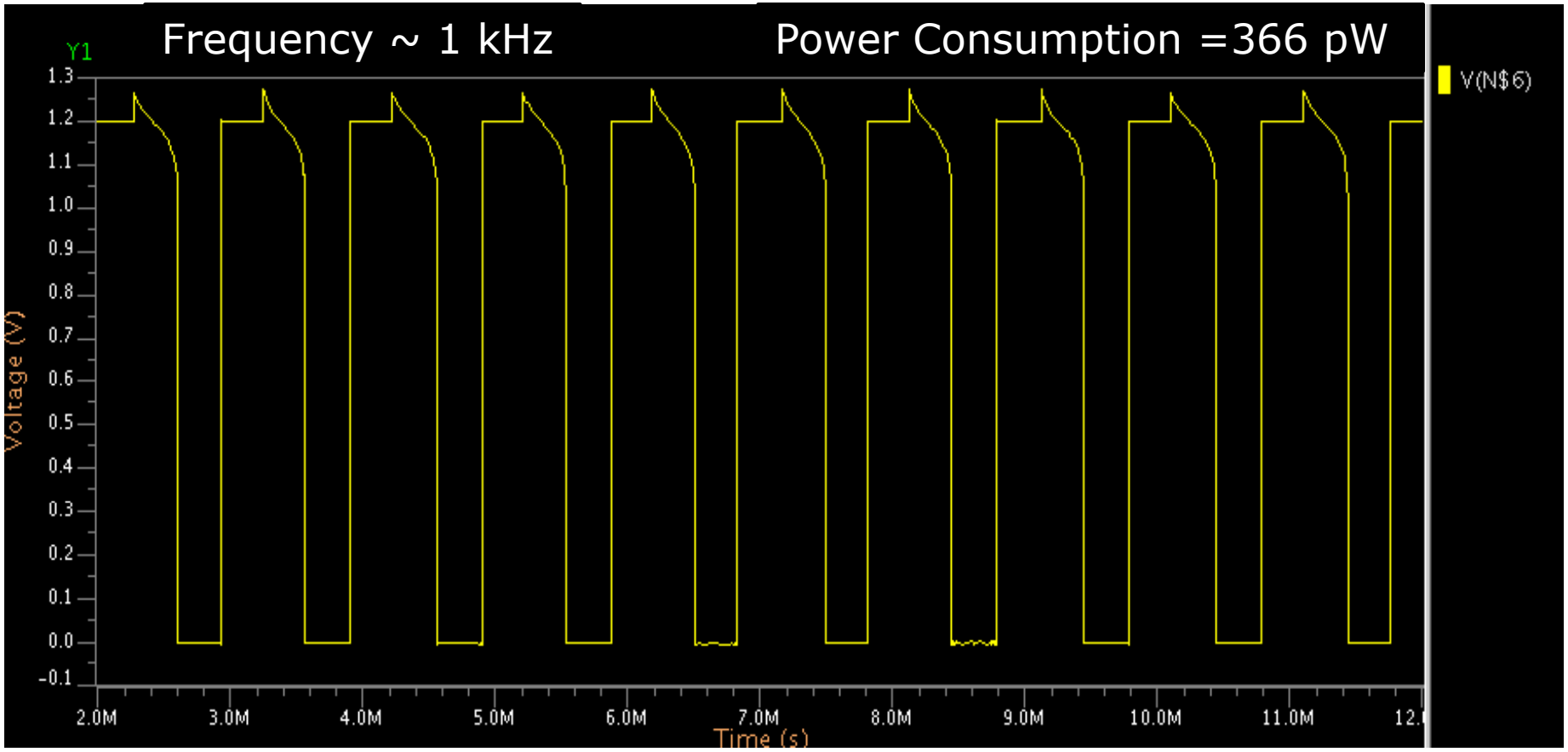
L=0.35um
W=1.4um

L=0.35um
W=2.8 um

CMOS Thyristor with Footer



CMOS Thyristor with Footer



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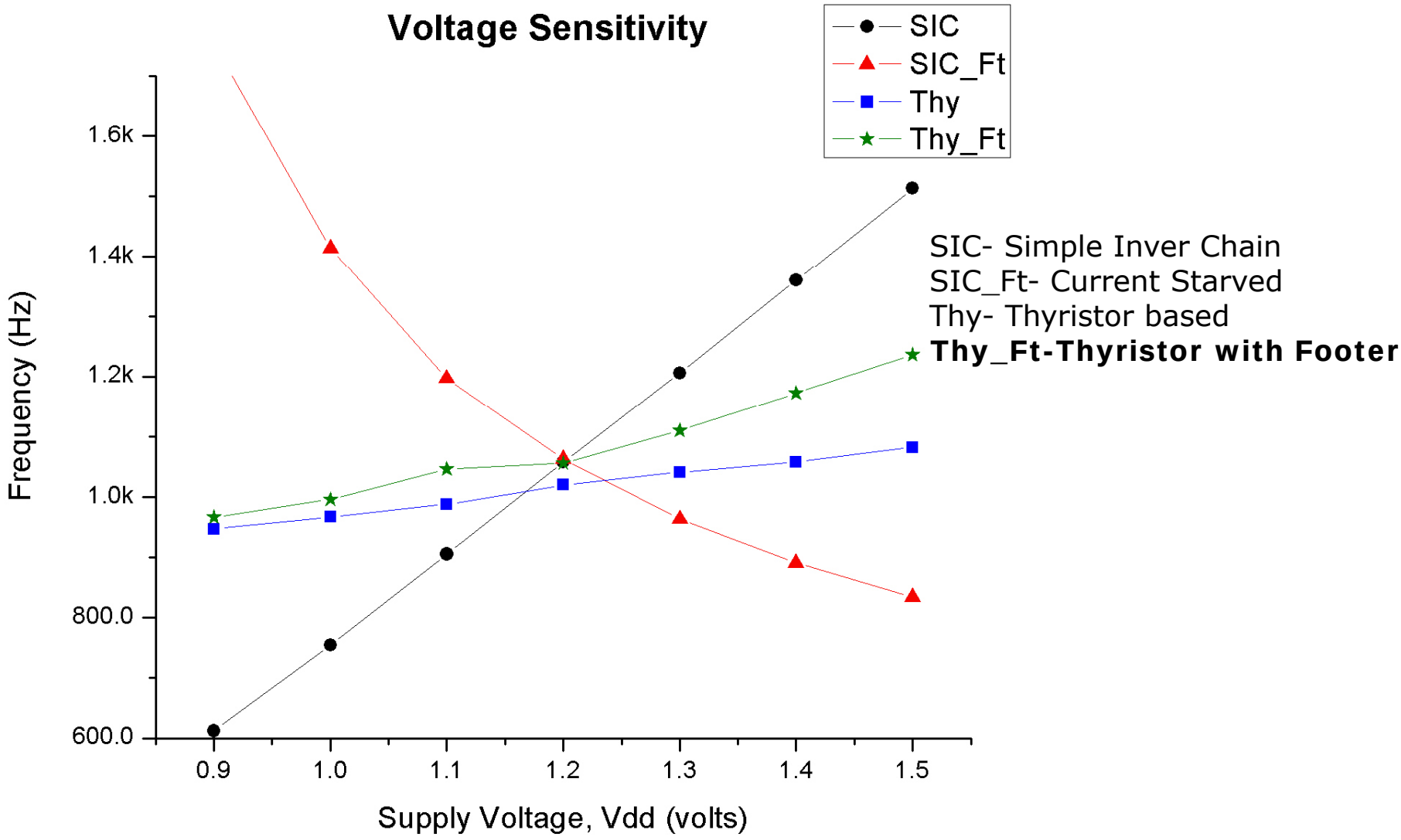
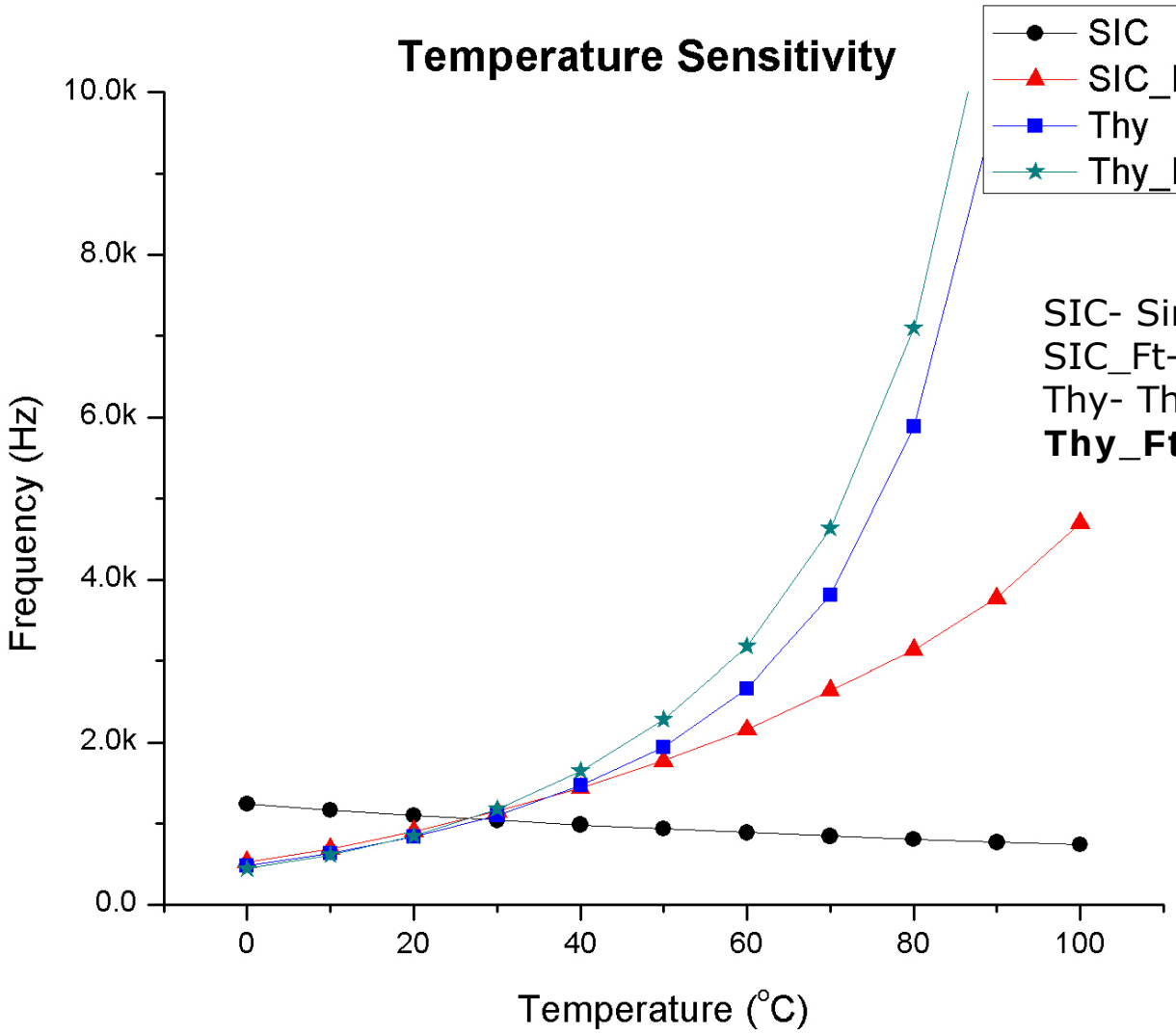
Summary of Results

	No. Of Inverters	W		L		Power (nW)
SVT Inverter Chain	601	1.4um		35um		716 nW
Current Starved SVT V_b=0.2V	3	1.4um		9um (inverting transistor)	0.35um (starving transistor)	2.9 nW
CMOS Thyristor	3	1.4um		1.5um (inverting transistor)	1.3um (triggering transistor)	0.59 nW
CMOS Thyristor Footer	3	1.4um (inverting transistor)	2.8um (footer transistor)	0.35um		**0.3 nW**

Voltage Sensitivity

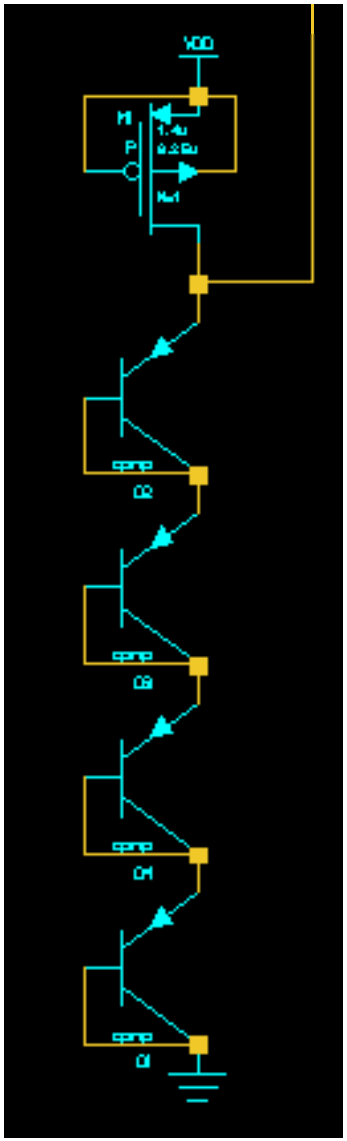


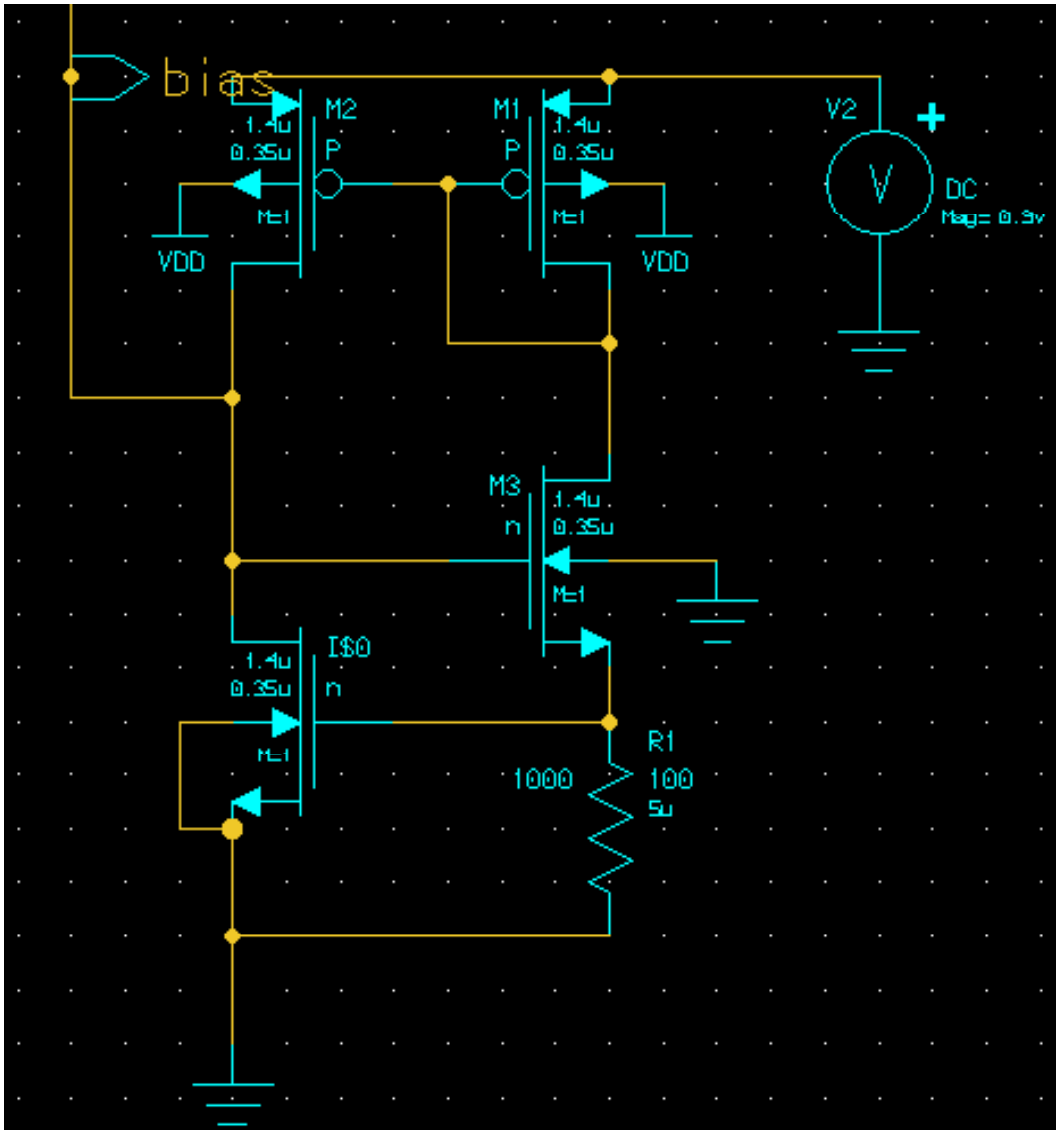
Temperature Sensitivity



SIC- Simple Inver Chain
SIC_Ft- Current Starved
Thy- Thyristor based
Thy_Ft-Thyristor with Footer

Temperature Compensation





References

- **Research Papers**

1. G. Kim, M.K. Kim, B.C. Chang, W. Kim; "A Low Voltage, Low Power CMOS Delay Element", IEEE journal of Solid-State Circuits, vol. 37, issue-7, July 1996, pp. 966-971.
2. J. Zhang, S.R. Cooper, A.R. Lapietra, M.W. Mattern, R.M. Guidash, E.G. Friedman; "A Low-Power Thyristor Based CMOS Programmable Delay Element", ISCAS'04, Proceedings of 2004 International Symposium, May 2004, pp. 769-762.
3. K. Sundaresan, P.E. Ellen, F. Ayazi; "Process and Temperature Compensation in a 7-MHz CMOS Clock Oscillator", IEEE journal of Solid-State Circuits, vol. 41, issue-2, Feb. 2006, pp. 433-442.

Thank you!