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Pursuing Excellence

A Tail-feedback VCO with Self-Adjusting Current Modulation Scheme

Aravind Tharayil Narayanan, Wei Deng, Kenichi Okada, and Akira Matsuzawa

Tokyo Institute of Technology, Japan

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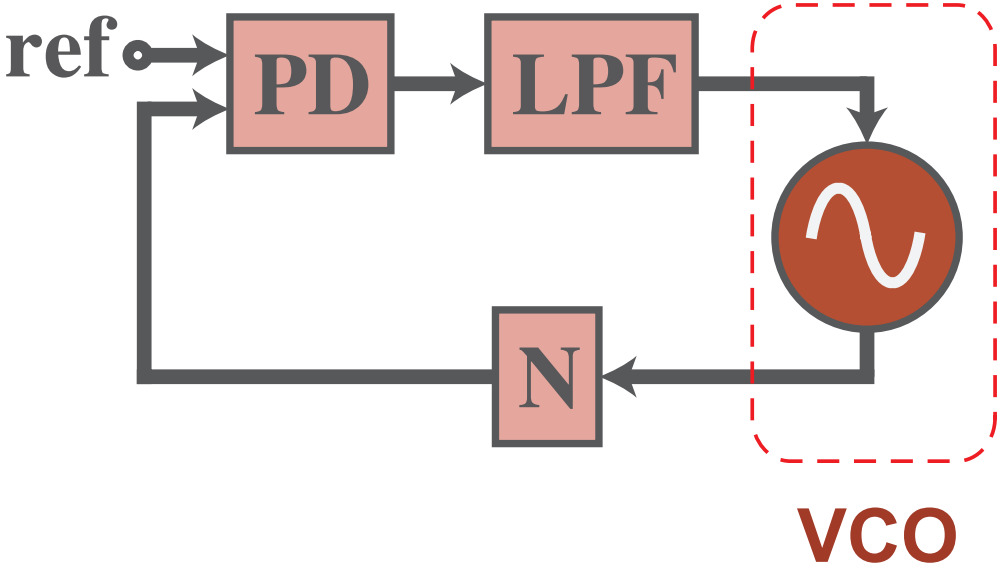
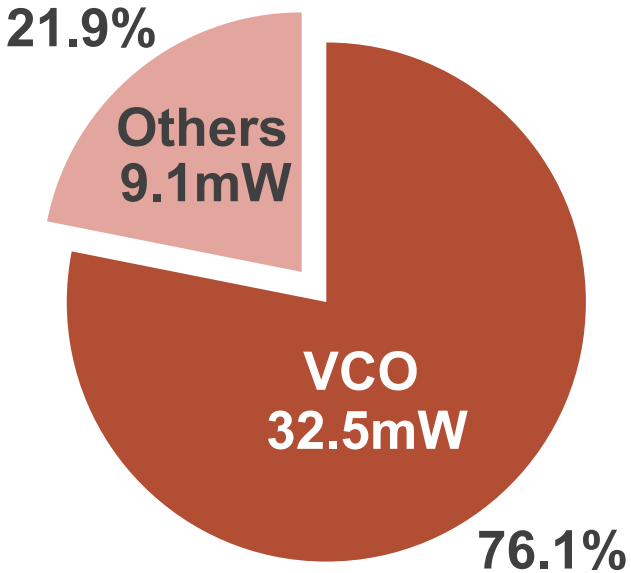
- Motivation
- High Efficiency VCOs
- Reliable Power-Efficient Solutions
- Startup issue in Tail-Feedback VCO
- Proposed VCO
- Tail-Bias *Vs* Class-C
- Measurement Results
- Conclusion

Motivation





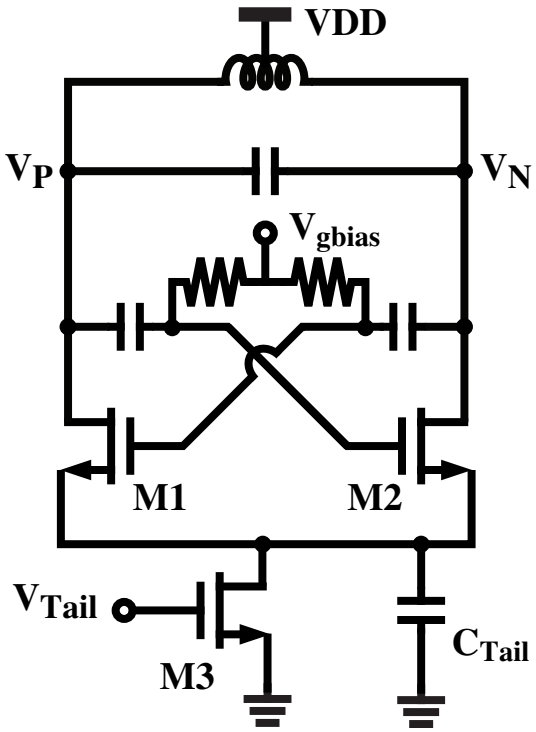
Aim:

- Low-power
- High-purity
- Long lifetime

➢ **Low-power VCO needed for longer battery-life**

[1] L. Vercesi, JSSC 2012.

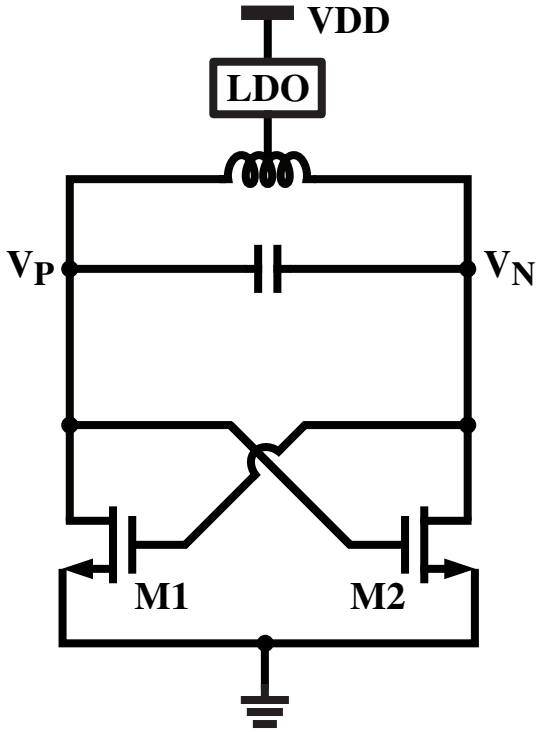
High Efficiency VCOs



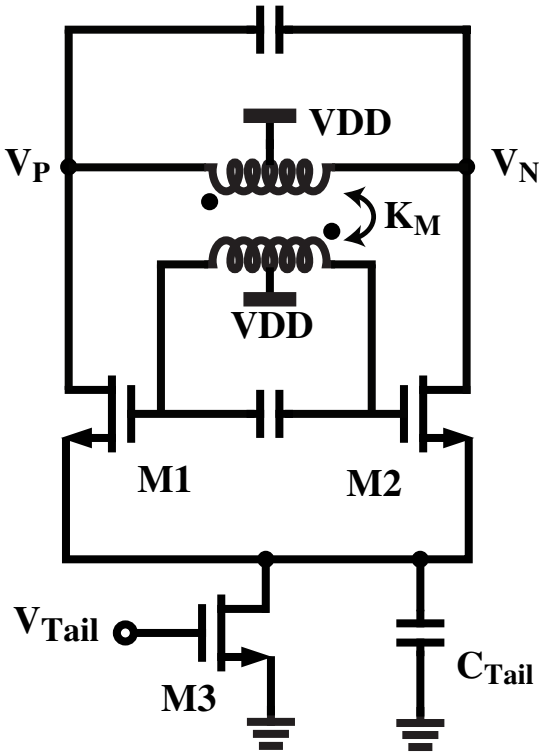
Class-C

High <u>current efficiency</u>

[2] P. Andreani, JSSC 2008.



Class-D



Class-F

High <u>voltage efficiency</u>

[3] L. Fanori, JSSC 2013.

[4] M. Babaie, JSSC 2013.

High Efficiency VCOs – *Contd.*

Excess Noise Factor[5] (ENF)

- **ENF = FoM_{MAX} – FoM**

  { FoM_{MAX} : Only depends on Q
  ENF : Only depends on topology

- **$ENF \propto \frac{1}{\eta_I \times \eta_V}$**

  η_I : Current efficiecny

  η_V : Voltage efficiecny

✗ **High η_V :**

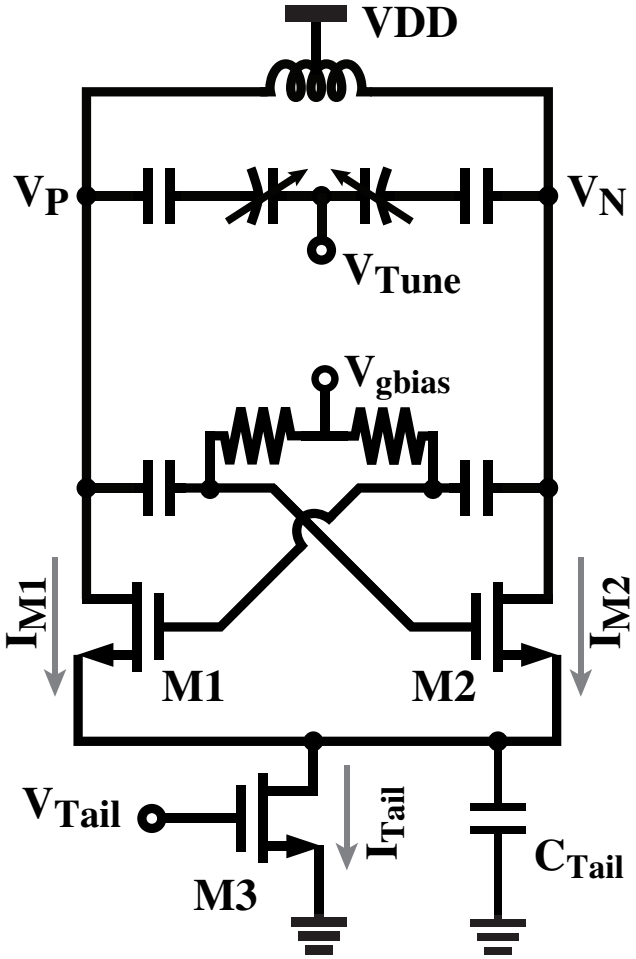
- Loading effects
- Reliability issues.

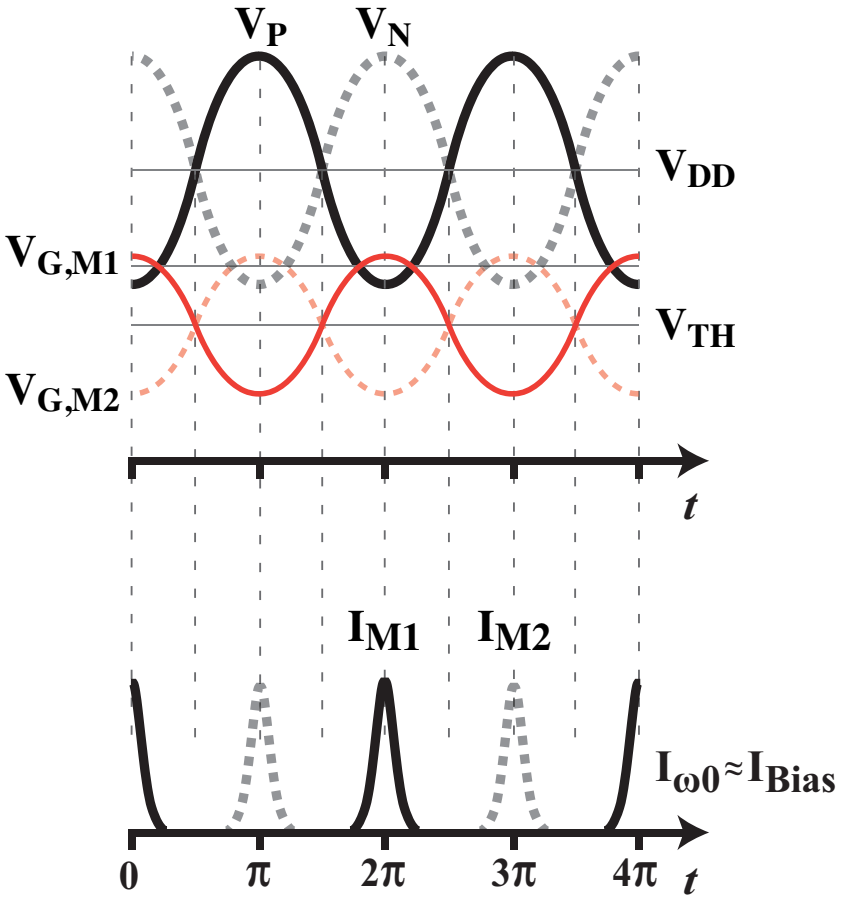
✓ **High η_I :**

- Good candidate for practical high efficiency VCO

[5] M. Garampazzi, ESSCIRC 2014.

Class-C VCO

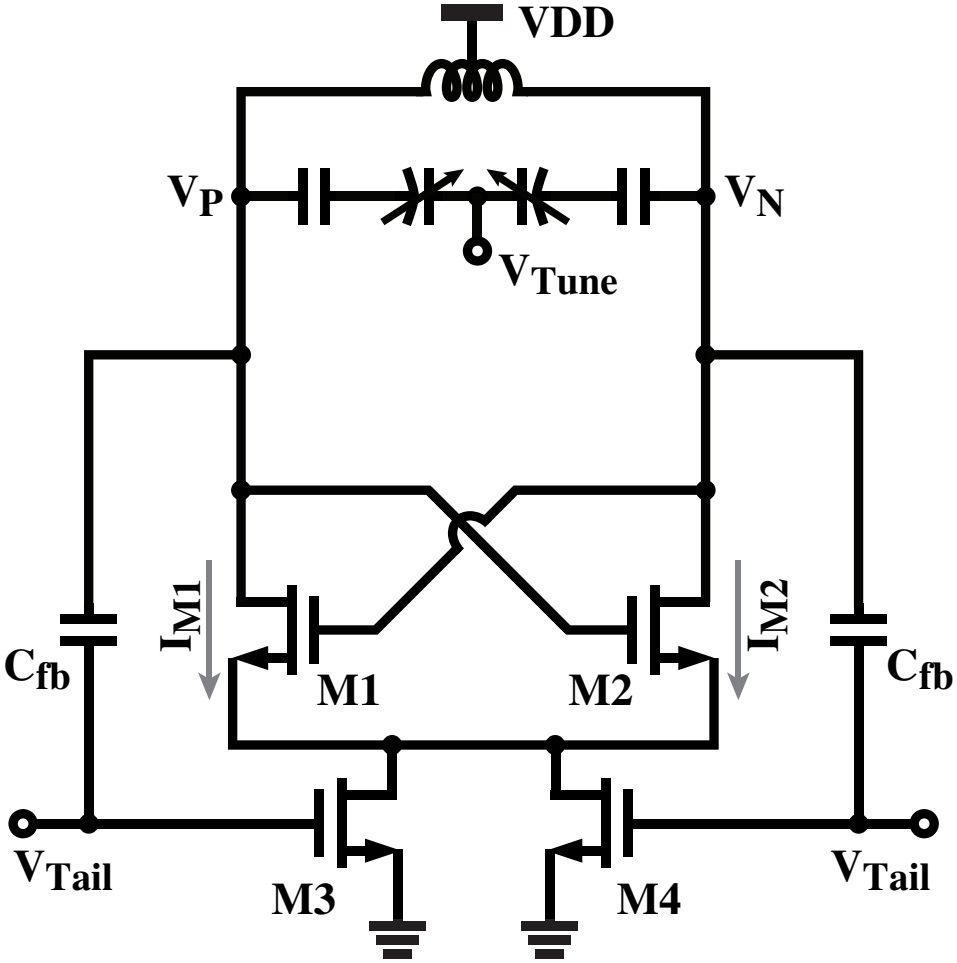


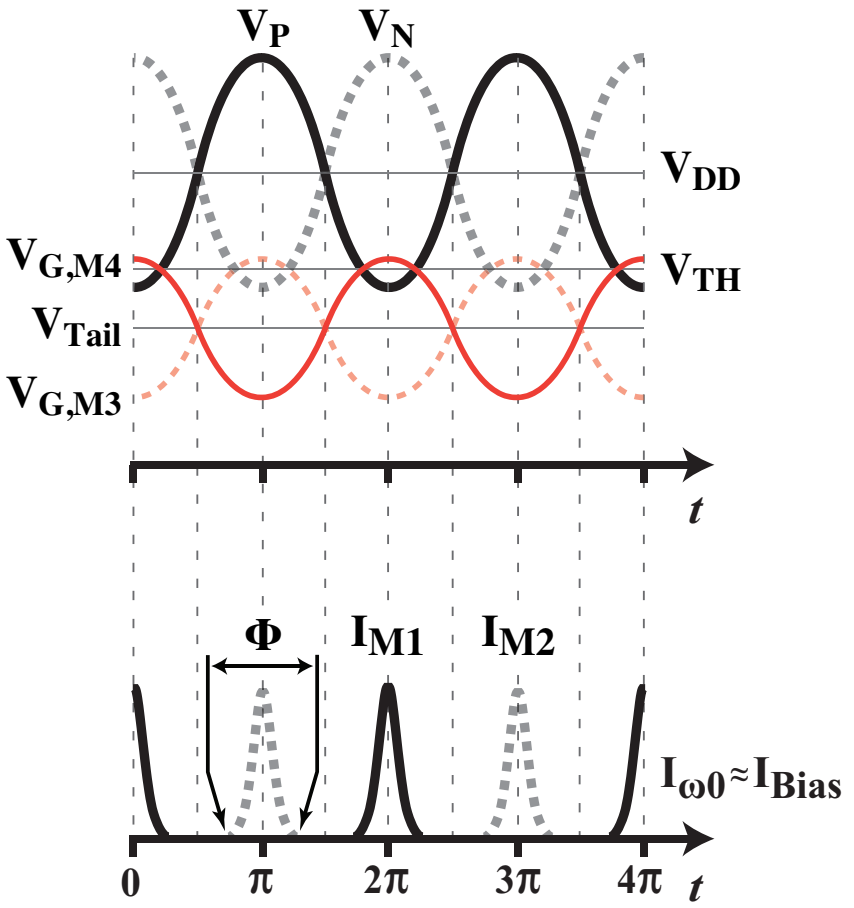


- **Impulse-shaped current for high efficiency**

[2] A. Mazzanti and P. Andreani, JSSC 2008.

Tail-Feedback VCO





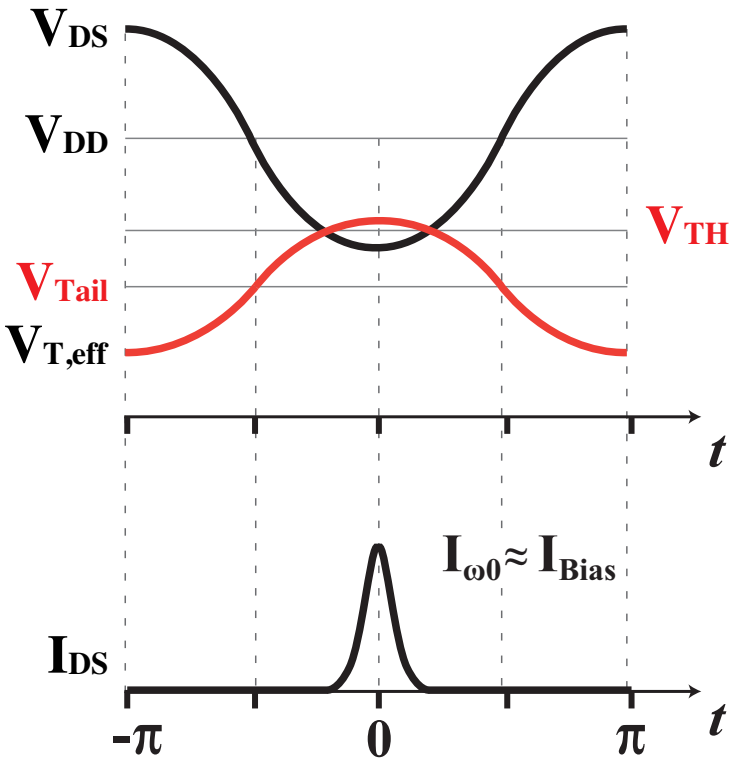
- **High efficiency can be achieved if Φ is small.**

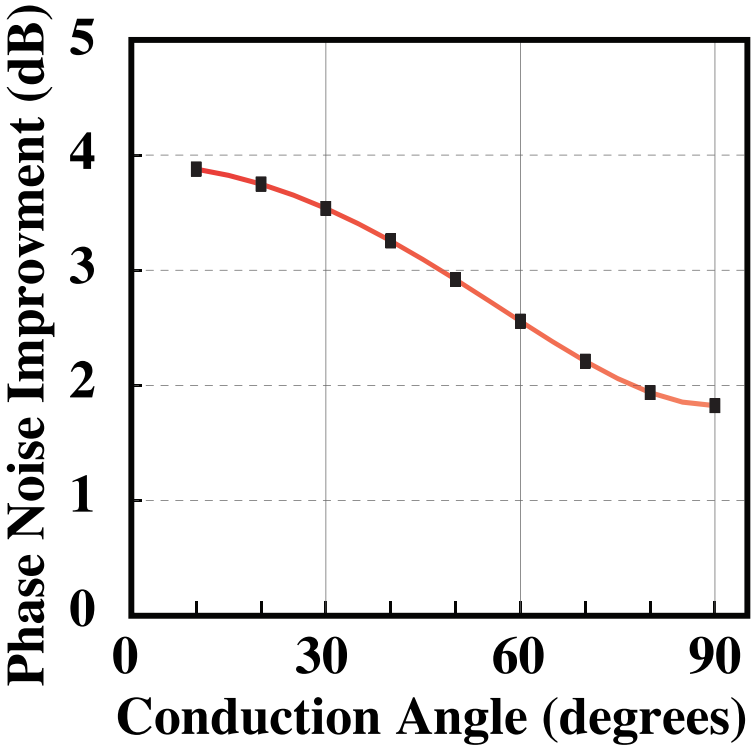
[6] A. Musa, IEICE 2013.

Startup Issue

- **Large oscillation amplitude for better phase noise**

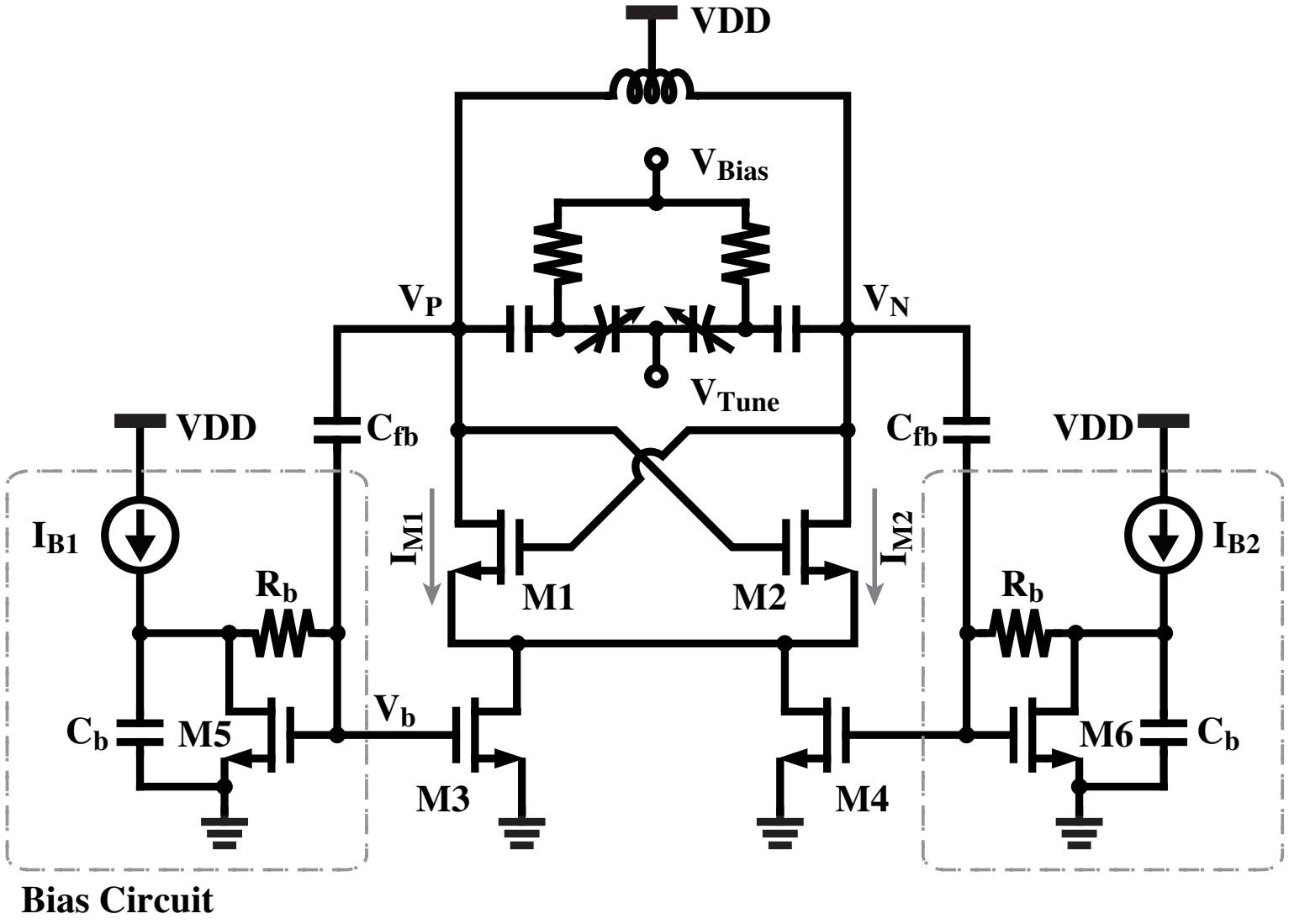
$$A_{out} = I_{DS} R_P$$



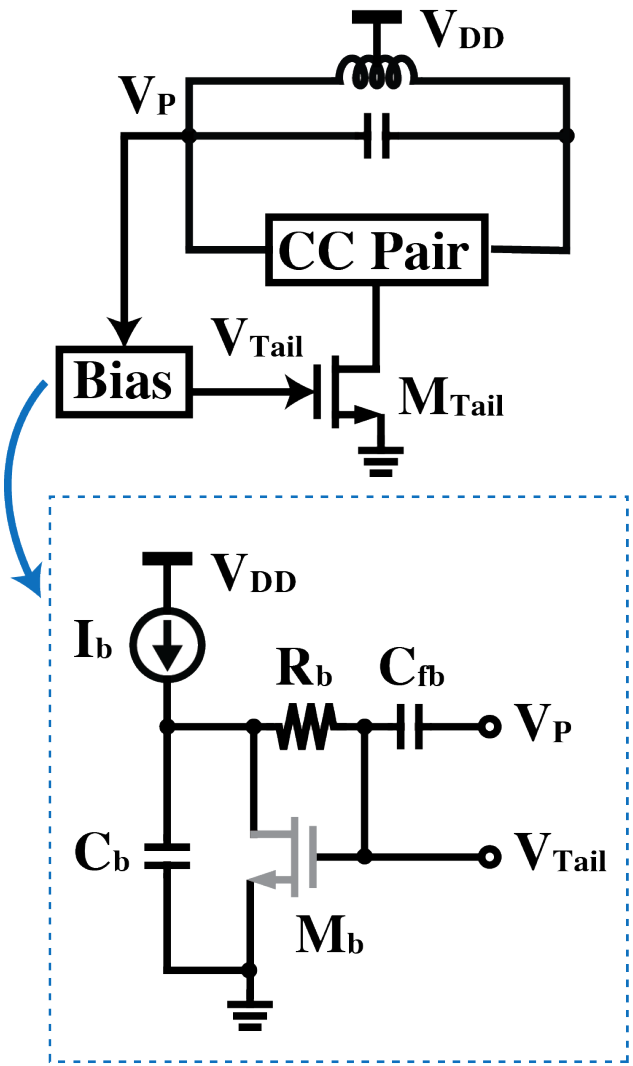


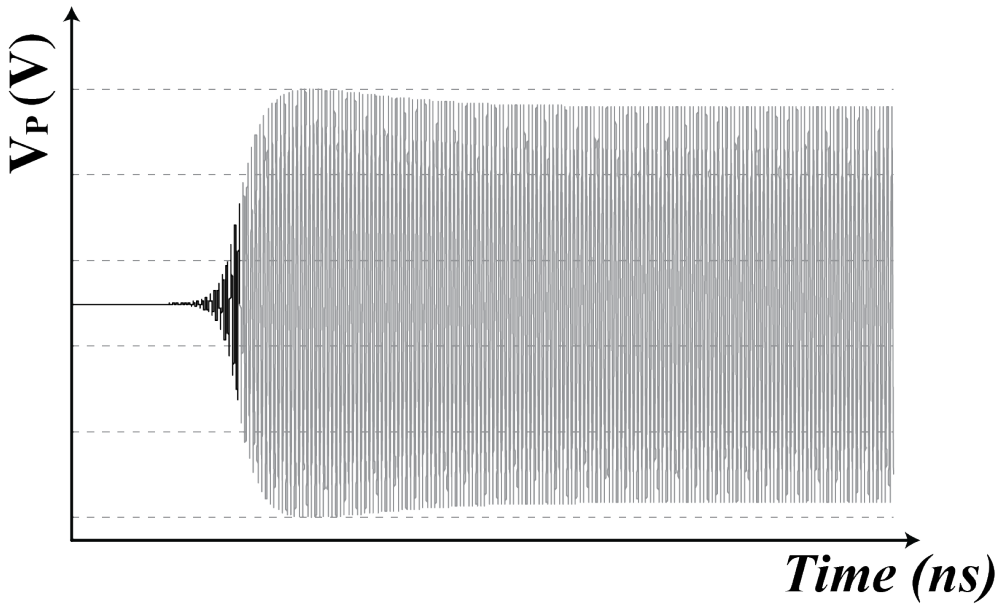
- **VCO fails to startup at low tail-bias voltage.**

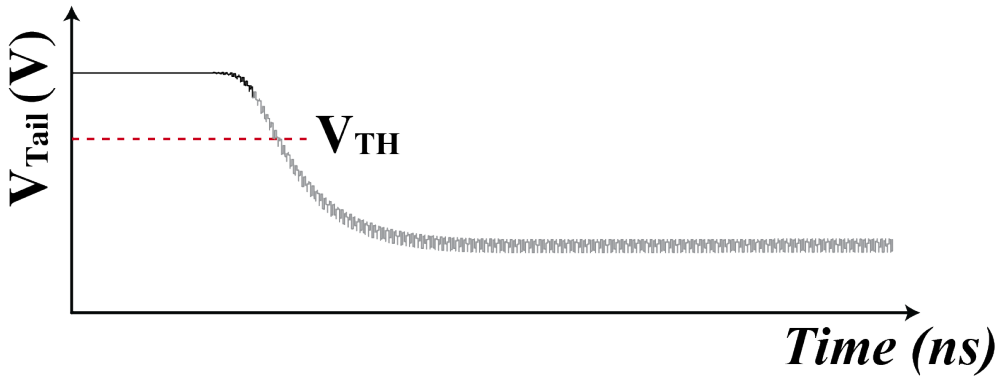
Proposed VCO



Self-Adjusting Tail-Current Modulation

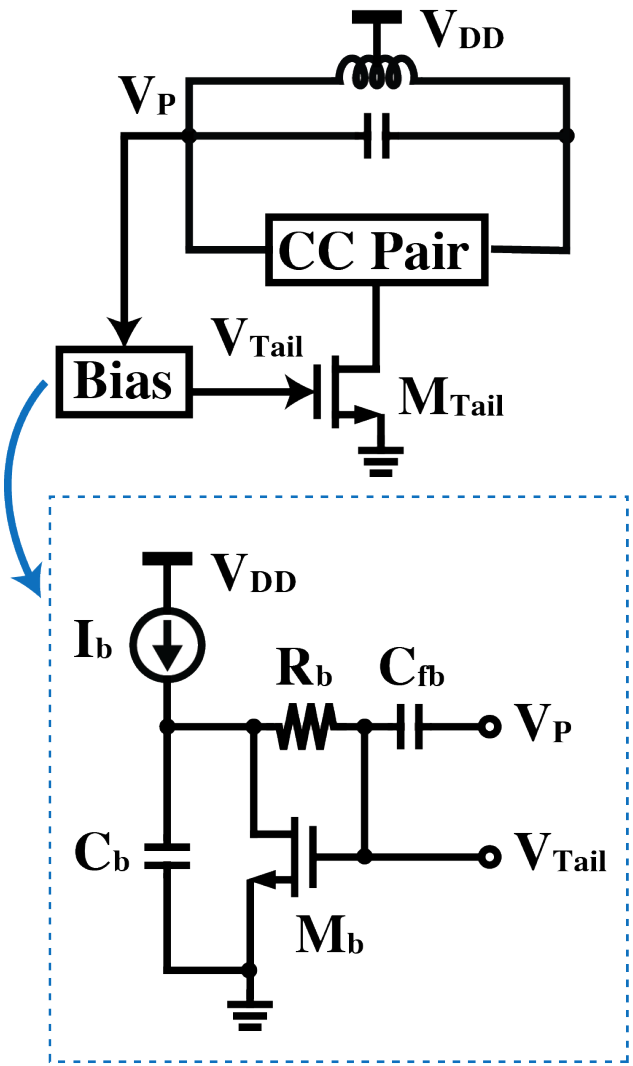


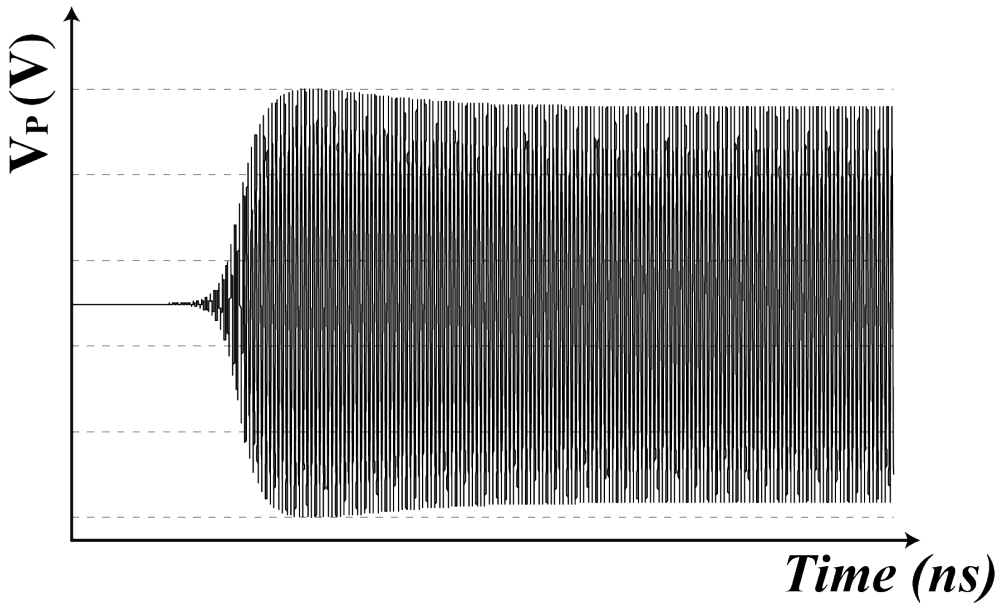


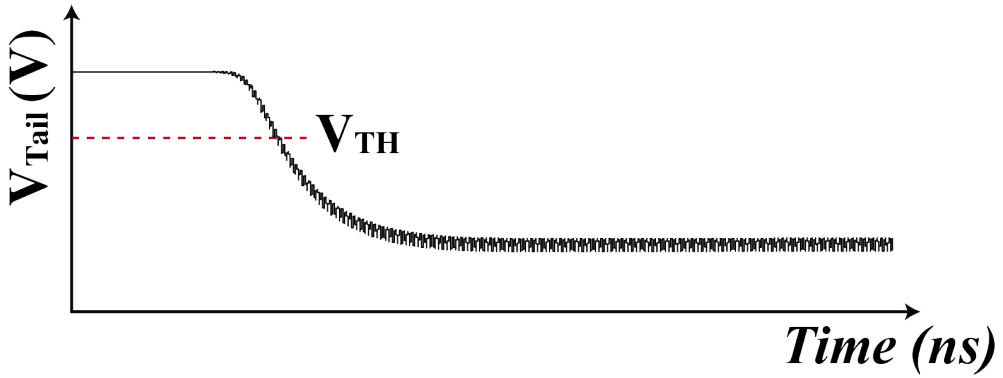


➢ **Ensures <u>robust startup</u>**

Self-Adjusting Tail-Current Modulation







- Optimizes ‘Φ’ for better phase noise

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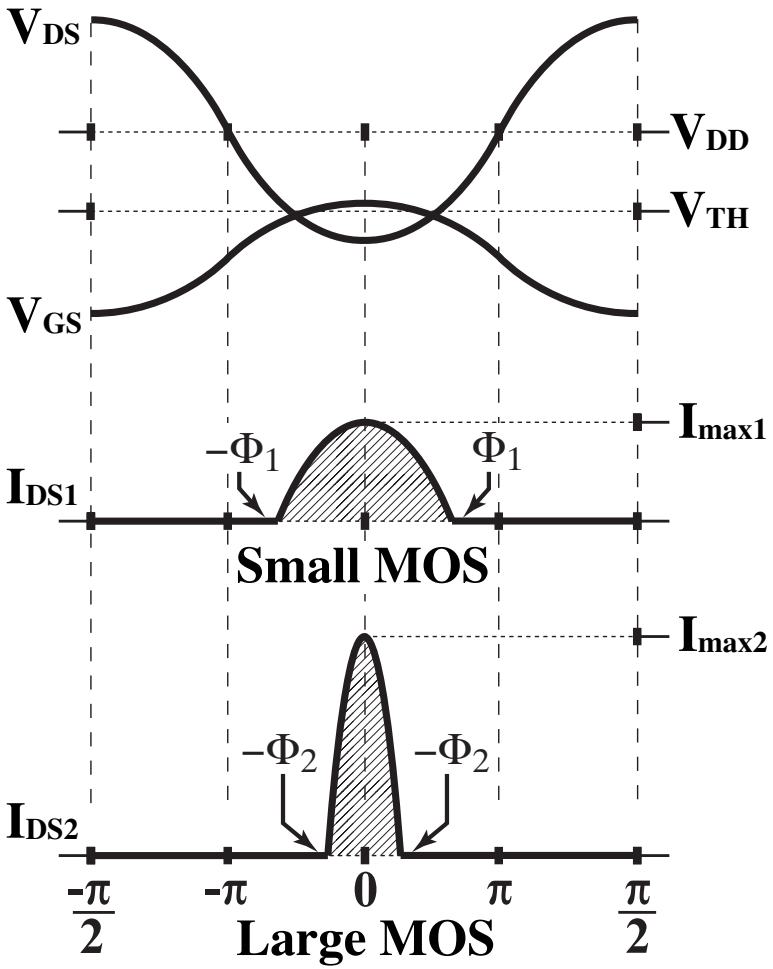
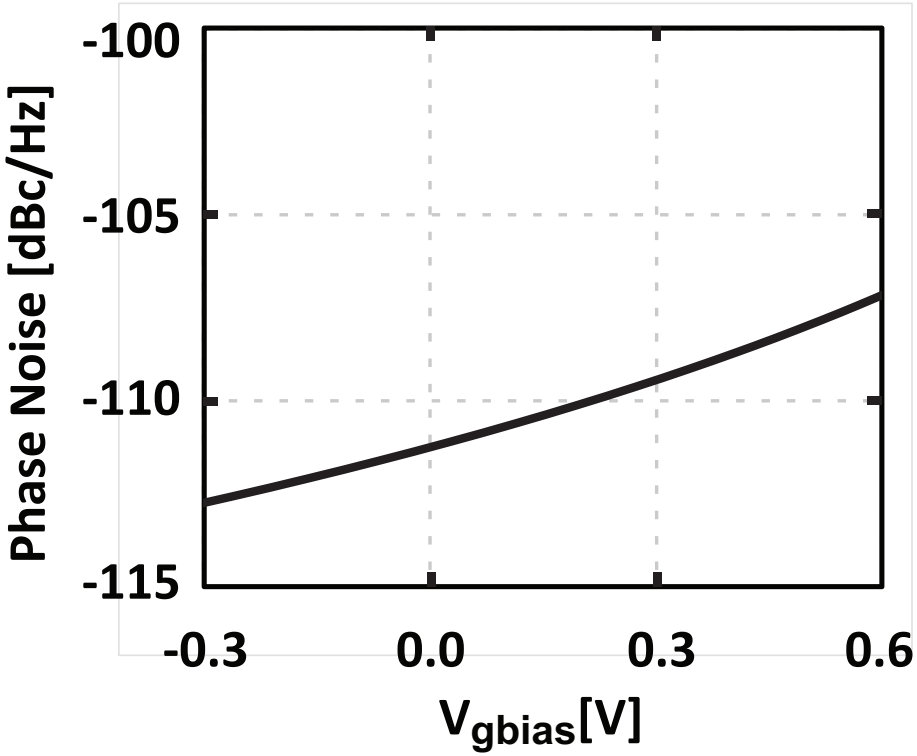
Efficiency and MOS Sizing in Class-C



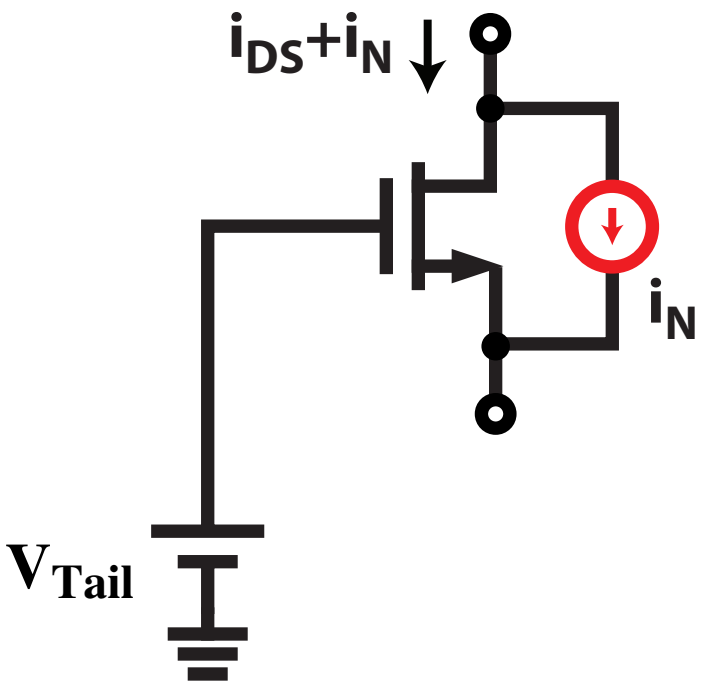
$$A_{max} = \frac{V_{DD} - (V_{GS} - V_{TH})}{2}$$



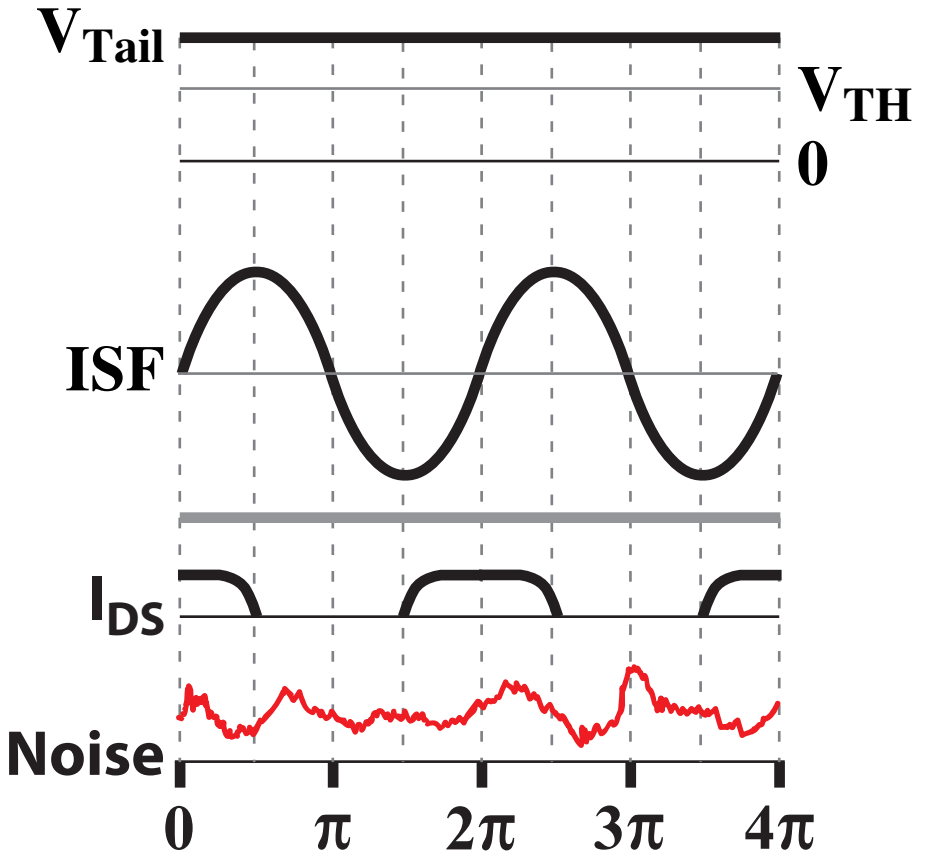
➢ **Large MOS required for better efficiency (class-C)**

[2] A. Mazzanti and P. Andreani, JSSC 2008.

Tail Noise Factor: Fixed Tail Bias



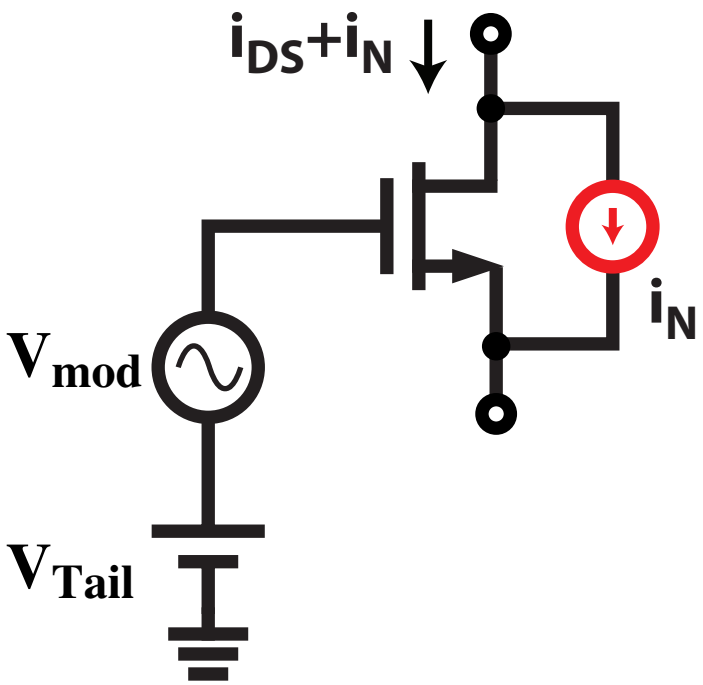
Fixed Tail Bias



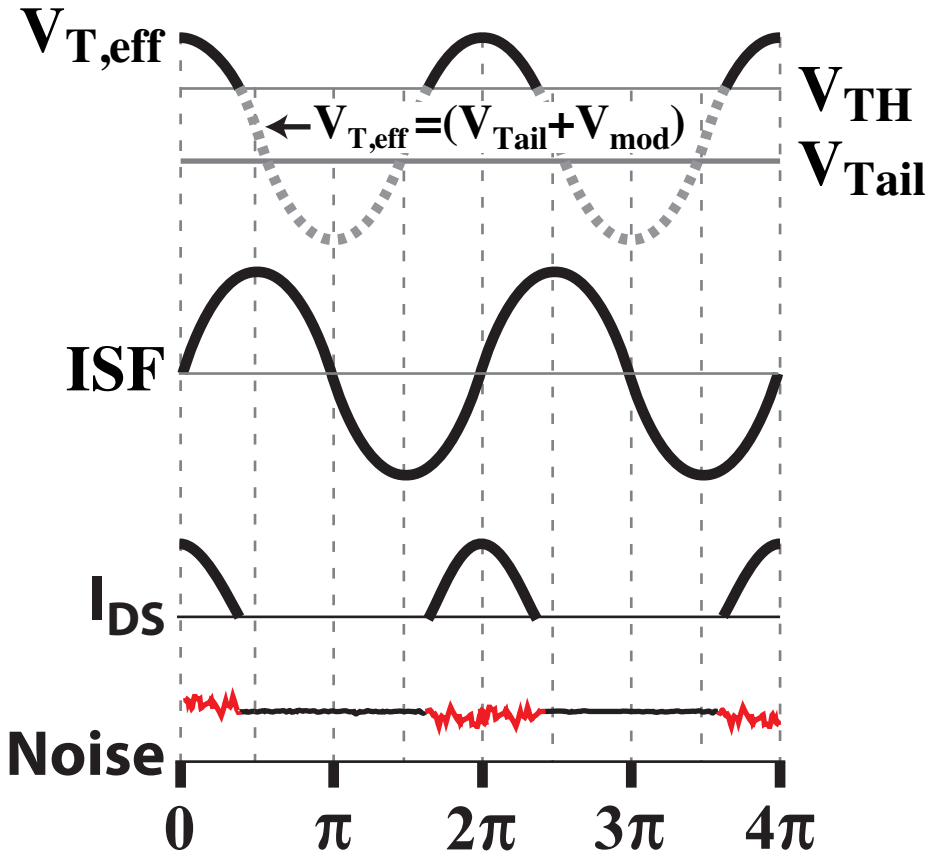
➢ **Continuous Tail-Noise Up-Conversion in Class-C**

[7] S.L.J. Geirkink, JSSC 1999.

Tail Noise Factor: Modulated Tail Bias



Modulated Tail Bias



➢ **Reduced Tail-Noise Up-Conversion**

[7] S.L.J. Geirkink, JSSC 1999.

In Brief

Tail-feedback VCO compared to class-C VCO

- **Better tuning range.**
- **Similar if not better noise performance.**
- **Start-up issue is solvable.**

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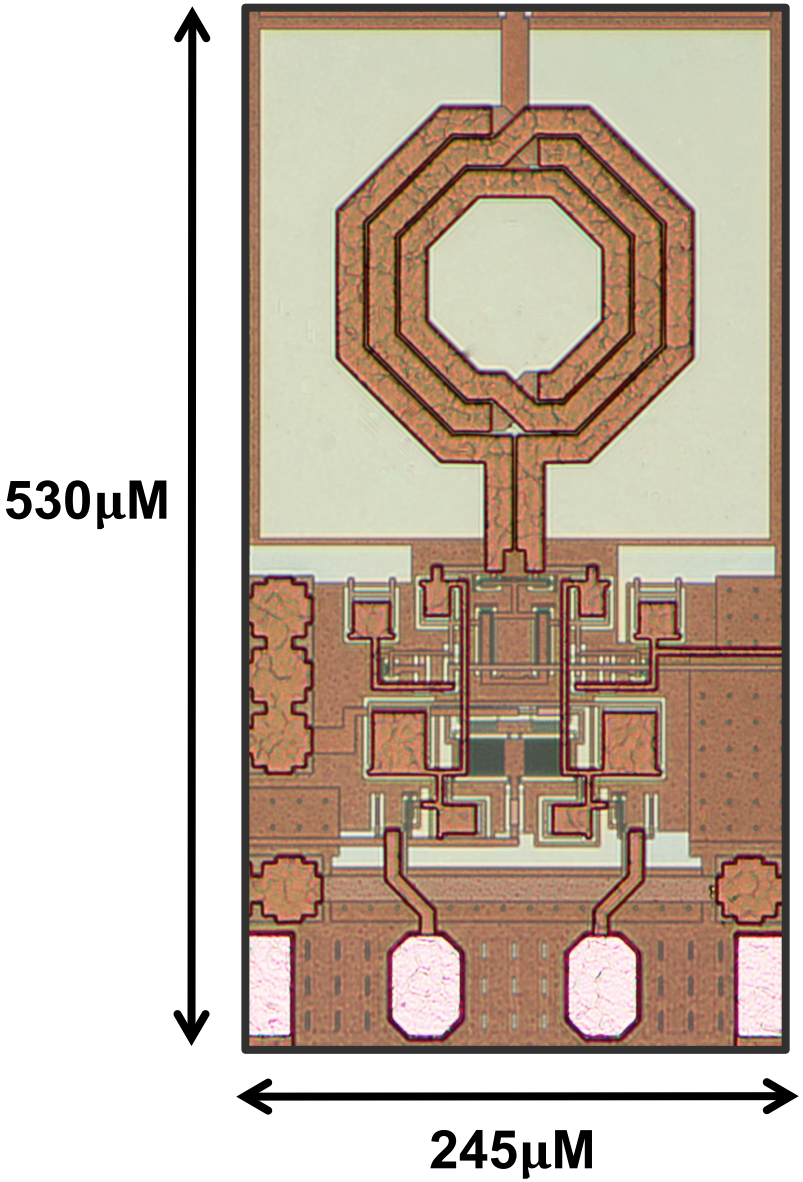
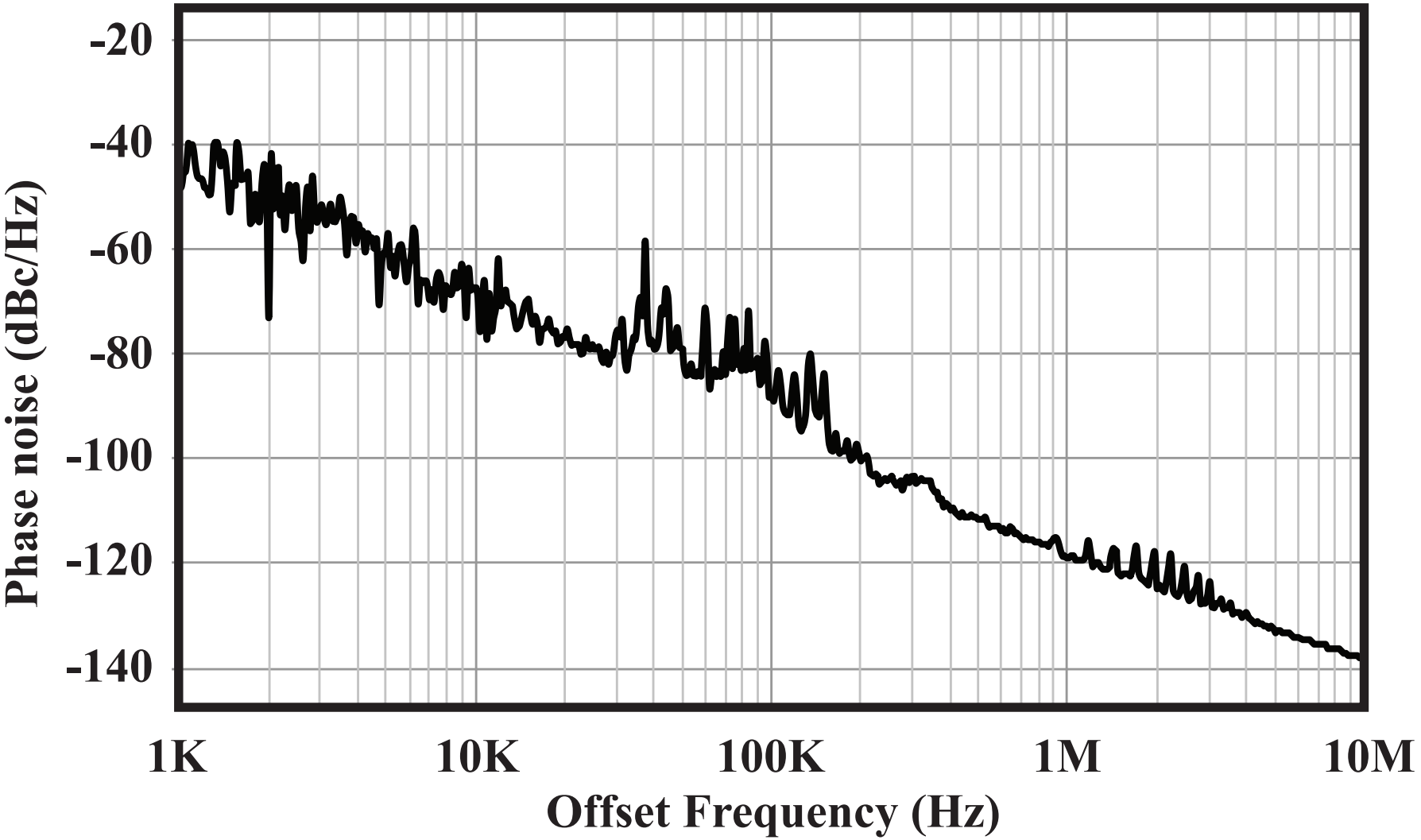
Measurement



Technology	180nm CMOS
F_{OSC}	4.6GHz
PN@1MHz	-119dBc/Hz
Power	6.8mW
FoM	-184dBc/Hz

Measurement

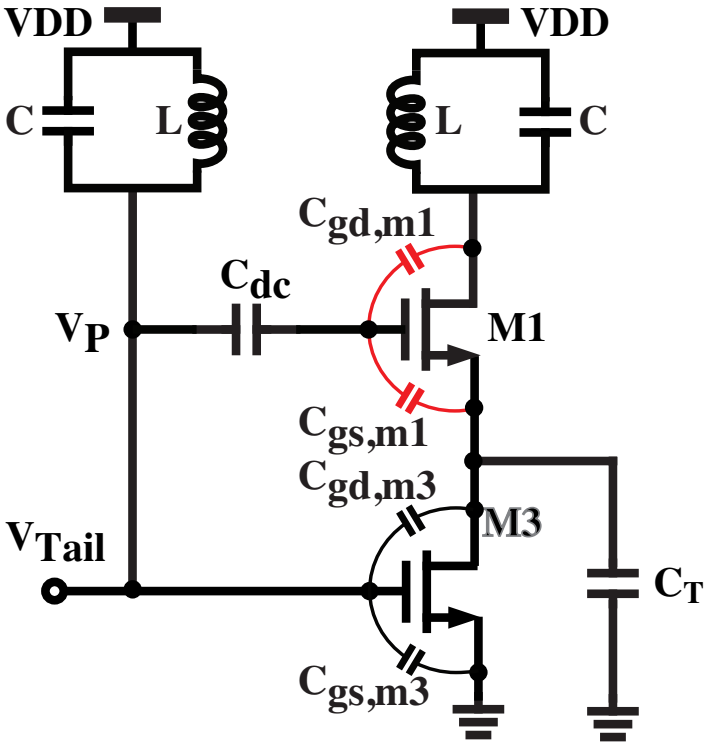


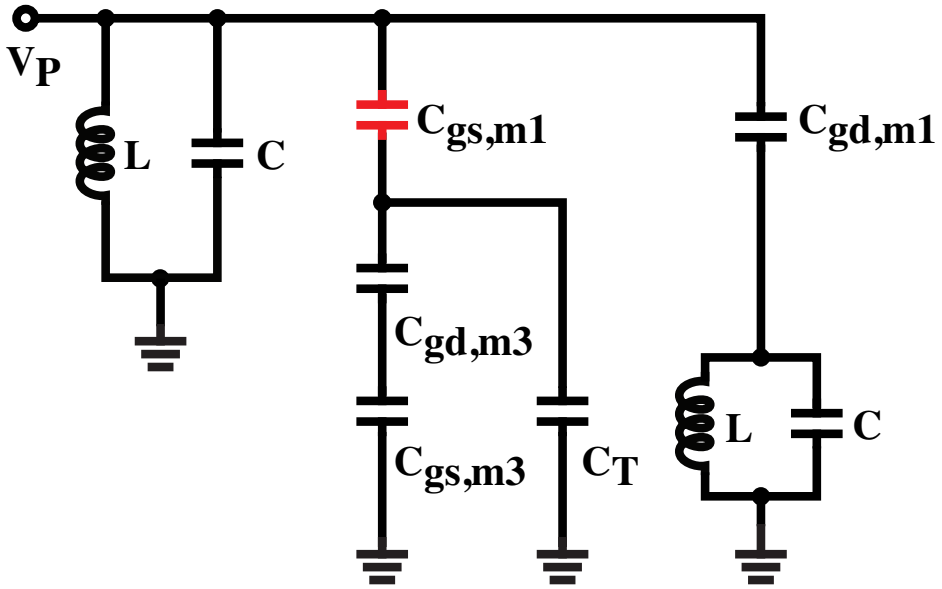
Conclusion

- **VCO topologies for high-efficiency is briefly analyzed.**
- **Current-efficient topology is identified as a viable candidate for practical design.**
- **Tail-feedback VCO is capable of achieving similar if not better performance compared to class-C VCO.**
- **The start-up issues present in tail-feedback VCO is briefly discussed.**
- **A bias mechanism is presented for solving startup issues.**
- **A VCO is implemented in 180nm CMOS process incorporating the proposed bias scheme.**

APPENDIX

Analysis: Class-C VCO

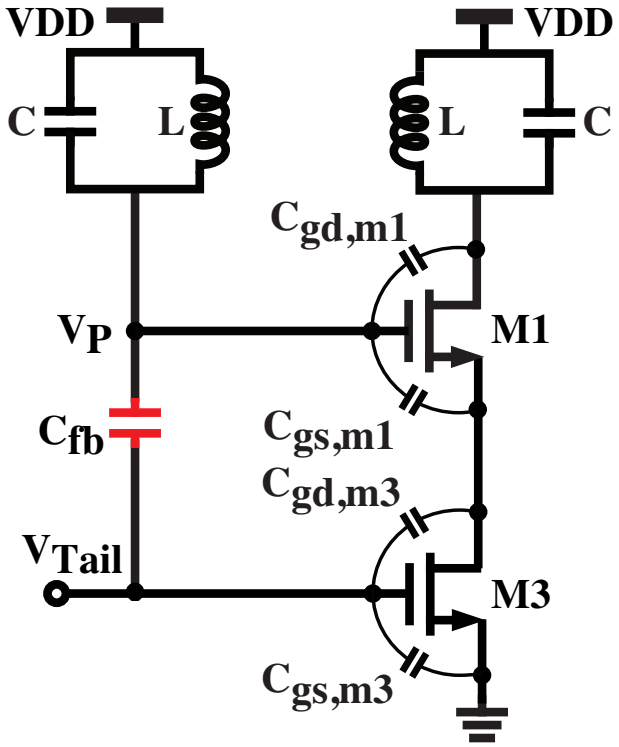


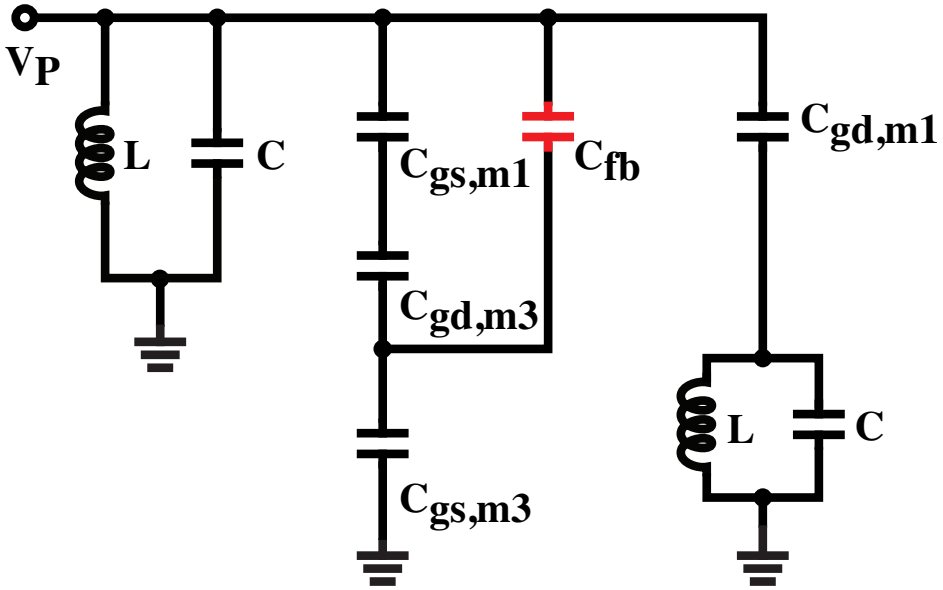


Conventioanl Class-C equivalent circuit

- C_{GS} has prominent effect on tank impedance

Analysis: Tail-Feedback VCO





Tail bias equivalent circuit

- Cross-couple size is independent of 'Φ'