CMOS Thyristor Based Low Frequency Ring Oscillator

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EE-610, Department Of Electrical Engineering, IIT Kanpur
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, \( N \rightarrow \) is the No. of delay cells.
  \( \tau_d \rightarrow \) 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

Vdd = 1.2 volts
L = 35um
W = 1.4um
Simple Inverter Chain

Frequency ~ 217 kHz
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

- \( L = 9 \text{um} \)
- \( W = 1.4 \text{um} \)
- \( L = 0.35 \text{um} \)
- \( W = 1.4 \text{um} \)
Current Starved Inverter Chain

$V_{dd} = 1.2 \text{ volts}$

$V_{bias} = 0.2 \text{ volts}$
Current Starved Inverter Chain

Frequency ≈ 1 kHz
Power Consumption = 2.91 nW
**Current Starved Inverter Chain**

**Issue**
- Voltage Sensitivity

![Graph showing the relationship between supply voltage and frequency](image)

**Graph Details**
- **x-axis**: Supply Voltage
- **y-axis**: Frequency
- Data points illustrating the decrease in frequency as the supply voltage increases.
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CMOS Thyristor Based Inverter

- Meta Stable Circuit
- Depend only on Leakage Current
CMOS Thyristor Based Inverter

Vdd = 1.2 volts
CMOS Thyristor Based Inverter

Frequency $\sim 1$ kHz  
Power Consumption = 592 pW

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- **CMOS Thyristor with Footer**
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Vdd = 1.2 volts
CMOS Thyristor with Footer

Frequency ~ 1 kHz
Power Consumption = 366 pW

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## Summary of Results

<table>
<thead>
<tr>
<th></th>
<th>No. Of Inverters</th>
<th>W</th>
<th>L</th>
<th>Power (nW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVT Inverter Chain</td>
<td>601</td>
<td>1.4um</td>
<td>35um</td>
<td>716 nW</td>
</tr>
<tr>
<td>Current Starved SVT</td>
<td>3</td>
<td>1.4um</td>
<td>9um</td>
<td>2.9 nW</td>
</tr>
<tr>
<td>(V_b=0.2V)</td>
<td></td>
<td></td>
<td>0.35um</td>
<td></td>
</tr>
<tr>
<td>CMOS Thyristor</td>
<td>3</td>
<td>1.4um</td>
<td>1.5um</td>
<td>0.59 nW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.3um</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(triggering transistor)</td>
<td></td>
</tr>
<tr>
<td>CMOS Thyristor Footer</td>
<td>3</td>
<td>1.4um</td>
<td>2.8um</td>
<td>0.3 nW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.35um</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(footer transistor)</td>
<td></td>
</tr>
</tbody>
</table>

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Voltage Sensitivity

Voltage Sensitivity

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

Supply Voltage, Vdd (volts)

Frequency (Hz)

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Temperature Sensitivity

Temperature Sensitivity

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

Graph showing the relationship between temperature (°C) and frequency (Hz) for different devices.
Temperature Compensation
References

• Research Papers


Thank you!