Sinc Filters Overview

C2000 Sigma Delta Filter Module (SDFM) Series
Sinc filters

- Cascaded Integrator-Comb (CIC) filters
- Configurable Low pass filter

\[
H(Z) = \left[ \frac{1 - Z^{-OSR}}{1 - Z^{-1}} \right]^N
\]

Z-Transform of Sinc filter of order N
Data rate and Latency

Data rate of Sinc filter = \( \frac{\text{Modulator data rate}}{\text{OSR}} \)

Latency of Sinc filter = \( \frac{\text{Order of Sinc filter}}{\text{Data rate of Sinc filter}} \)

Step Response of Sinc Filters with same OSR

- Poor resolution but with faster settling time
- Better resolution at the cost of slower settling time
Ideal Low Pass Filter

Ideal Low pass filter passes all signals below cut-off frequency ($f_c$) without any distortion and completely attenuates all signals above the cut-off frequency

Transfer function of ideal low pass filter

$$H(f) = \begin{cases} 
1 & \text{for } f \leq f_c \\
0 & \text{for } f > f_c 
\end{cases}$$
Understanding Sinc Filter Frequency Response

For same OSR settings, higher order Sinc filters provides better noise attenuation for the same data rate and higher latency.

- **OSR = 32**
- **SD Modulator Data rate = 20 MHz**

<table>
<thead>
<tr>
<th>Filter</th>
<th>OSR</th>
<th>Order</th>
<th>Weighted average</th>
<th># SD data samples</th>
<th>Data rate</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinc1</td>
<td>32</td>
<td>1</td>
<td>32 SD-modulated bitstreams</td>
<td>32 bitstreams (1 x OSR)</td>
<td>1.6 us</td>
<td>1.6 us</td>
</tr>
<tr>
<td>Sinc2</td>
<td>32</td>
<td>2</td>
<td>32 Sinc1 filter data</td>
<td>64 bitstreams (2 x OSR)</td>
<td>1.6 us</td>
<td>3.2 us</td>
</tr>
<tr>
<td>Sinc3</td>
<td>32</td>
<td>3</td>
<td>32 Sinc2 filter data</td>
<td>96 bitstreams (3 x OSR)</td>
<td>1.6 us</td>
<td>4.8 us</td>
</tr>
</tbody>
</table>
Understanding Sinc Filter Frequency Response

For same Filter Type, increasing the OSR settings provides better noise attenuation at slower data rate and higher latency

<table>
<thead>
<tr>
<th>Filter</th>
<th>OSR</th>
<th>Order</th>
<th>Weighted average</th>
<th># SD data samples</th>
<th>Data rate</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinc3</td>
<td>8</td>
<td>1</td>
<td>8 Sinc2 filter data</td>
<td>24 SDCLKs</td>
<td>1.6 us</td>
<td>1.6 us</td>
</tr>
<tr>
<td>Sinc3</td>
<td>16</td>
<td>2</td>
<td>16 Sinc2 filter data</td>
<td>48 SDCLKs</td>
<td>1.6 us</td>
<td>3.2 us</td>
</tr>
<tr>
<td>Sinc3</td>
<td>24</td>
<td>3</td>
<td>24 Sinc2 filter data</td>
<td>92 SDCLKs</td>
<td>1.6 us</td>
<td>4.8 us</td>
</tr>
</tbody>
</table>
Performance metrics

Short circuit detection requirement: 6 ENOB under 2us

High Resolution data: 12 ENOB

Sinc3, OSR = 10 with settling time of 1.5 us
Sinc3, OSR = 60 with settling time of 9 us

Courtesy: AMC1304 datasheet
Additional SDFM Resources

Foundational Materials

- How delta-sigma ADCs work, Part 1
- How delta-sigma ADCs work, Part 2
- Nuts and Bolts of the Delta-Sigma Converter (video)
- C2000 Academy with Hands-on Labs

Expert Materials

- Achieving Better Signal Integrity With Isolated Delta-Sigma Modulators in Motor Drives
- C2000 DesignDRIVE Development Kit for Industrial Motor Control
- Isolated Current Shunt and Voltage Measurement Kit
- Three Phase Power Factor Correction Reference Design Using C2000 MCU

Check Video Description for Additional Resources