

ADE7912/ADE7913 Front-End DSP Specifications

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INTRODUCTION

This application note explains several aspects of the digital filtering associated with the Σ - Δ modulators used in the [ADE7912/ADE7913](#). The role of the filters is to decimate the outputs of the modulators to various rates, while eliminating high frequency noise. These rates start from a high of 8 kHz and go as low as 1 kHz, allowing the user to update the rates to the microcontroller processing bandwidth.

DIGITAL DECIMATION FILTERING

Functional Description

Figure 1 shows the block diagram of the decimation filtering implemented in the [ADE7912/ADE7913](#). The Σ - Δ modulator provides a bit stream with a frequency of 1 MHz when the chip is clocked at $CLKIN = 4.096$ MHz. The SINC4 filter uses four decimation ratios—32, 64, 128, and 256—to provide outputs at 32 kHz, 16 kHz, 8 kHz and 4 kHz. To limit the bandwidth to meaningful frequencies while also keeping the data rate as low as possible, an extra low-pass filter (LPF) with 60 dB attenuation is used. This makes the subsequent rms and power calculations

more precise, reducing the bandwidth a micro-controller must reserve for the metrology calculations.

The LPF performs another decimation by 4, and has internal flexibility, which leads to two different bandwidths. The LPF is implemented as two separate, sixth-order filters: one filter for the narrower bandwidths, one filter for the larger bandwidths.

The [ADE7912/ADE7913](#) provide multiple output data rates (ODRs): 8 kHz, 4 kHz, 2 kHz, and 1 kHz, as well as two selectable bandwidths for each of these rates (see Table 1). The selectable ODRs help users address a wide range of scenarios to make their own trade-offs in the datapaths implemented in the microcontroller.

ODR and bandwidth selection is performed by Bit 7 (BW) and Bits[5:4] (ADC_FREQ) in the CONFIG register. Table 1 shows the different BW and ADC_FREQ settings required when the [ADE7912/ADE7913](#) is clocked at $CLKIN = 4.096$ MHz. The bandwidth is indicated by the point at which the gain is attenuated by 3 dB.

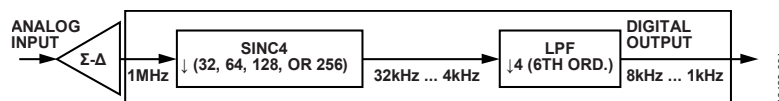


Figure 1. Block Diagram of the Decimation Filtering Implemented in the [ADE7912/ADE7913](#)

Table 1. CONFIG Register Settings for Obtaining Various ODRs and Bandwidths

CONFIG Register		ODR (kHz)	SINC4 + LPF Bandwidth (kHz)
Bits[5:4] (ADC_FREQ) Setting	Bit 7 (BW) Setting		
00	0	8	3.338
00	1	8	2.137
01	0	4	1.670
01	1	4	1.069
10	0	2	0.836
10	1	2	0.535
11	0	1	0.418
11	1	1	0.268

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REVISION HISTORY

8/15—Revision 0: Initial Version

FREQUENCY RESPONSE AND TIME DELAY CHARACTERISTICS OF THE SINC4 + LPF FILTERS

The equivalent Z-domain formula of the SINC4 for various decimation ratios (DRs) is shown in the following equation:

$$SINC4(z) = \left[\frac{1 - z^{-DR}}{1 - z^{-1}} \right]^4$$

The Z-domain formula of the LPF that corresponds to the narrower bandwidth (BW, Bit 7 of the CONFIG register, is set to 1) is shown in the following equation:

$$LPF_BW1(z) = \frac{(1 + 1.15478515625 \times z^{-1})}{(1 - 0.7138671875 \times z^{-1})} \times \frac{(1 - 0.6630859375 \times z^{-1} + z^{-2})}{(1 - 1.5068359375 \times z^{-1} + 0.6162109375 \times z^{-2})} \times \frac{(1 - 1.333984375 \times z^{-1} + z^{-2})}{(1 - 0.6962890625 \times z^{-1} + 0.8544921875 \times z^{-2})}$$

where *LPF_BW1* is the LPF that corresponds to the narrower bandwidth.

The Z-domain formula of the LPF that corresponds to the larger bandwidth (BW, Bit 7 of the CONFIG register, is cleared to 0) is shown in the following equation:

$$LPF_BW2(z) = \frac{(1 + 1.15478515625 \times z^{-1} + z^{-2})}{(1 - 1.205322265625 \times z^{-1} + 0.385498046875 \times z^{-2})} \times \frac{(1 - 0.603759765625 \times z^{-1} + z^{-2})}{(1 - 1.31005859375 \times z^{-1} + 0.589111328125 \times z^{-2})} \times \frac{(1 - 1.0595703125 \times z^{-1} + z^{-2})}{(1 - 1.470947265625 \times z^{-1} + 0.856201171875 \times z^{-2})}$$

where *LPF_BW2* is the LPF that corresponds to the larger bandwidth.

MAGNITUDE FREQUENCY RESPONSE AND TIME DELAYS FOR VARIOUS FILTERS

Figure 2 through Figure 25 and Table 2 through Table 32 provide detailed information about the magnitude frequency response and the time delays introduced in the signal path by the various filters. The output data rate (ODR) is the output frequency at which the analog-to-digital converter (ADC) samples are provided by the [ADE7912/ADE7913](#). The bandwidth of the filter (BW) is the point at which the gain is attenuated by 3 dB. The full frequency response, or the response up to the -3 dB point, and the flat-band response (from 0 dB down to -0.8 dB attenuation) are shown in all ODR and BW cases.

The phase delay defines the propagation delay in the phase of a sinusoidal signal passing through the filter. Tables showing the phase delay at various frequencies are shown for all ODR and BW cases.

From the perspective of power calculations, these time delays do not affect the final results because both voltage and current signals are subject to identical time delay propagation. However, in case of transient events or events synchronous to the zero crossings, it may be useful to know the time delays.

The frequency points are selected in such a way that the intermediate values can be obtained with accuracy by piecewise linear interpolation. These frequency points may be useful, for example, if amplitude corrections are necessary.

ODR = 8 kHz and BW = 3.338 kHz

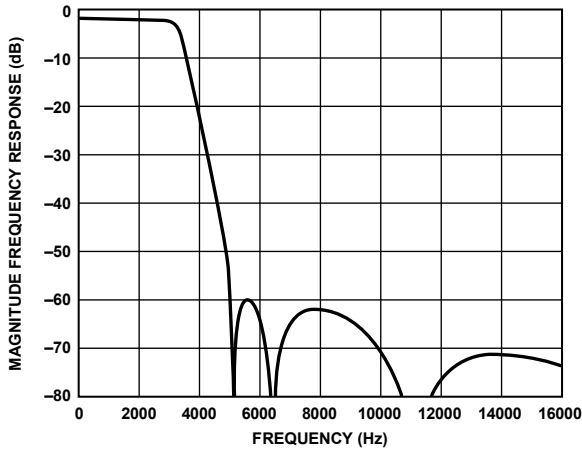


Figure 2. Full Frequency Response for ODR = 8 kHz and BW = 3.338 kHz

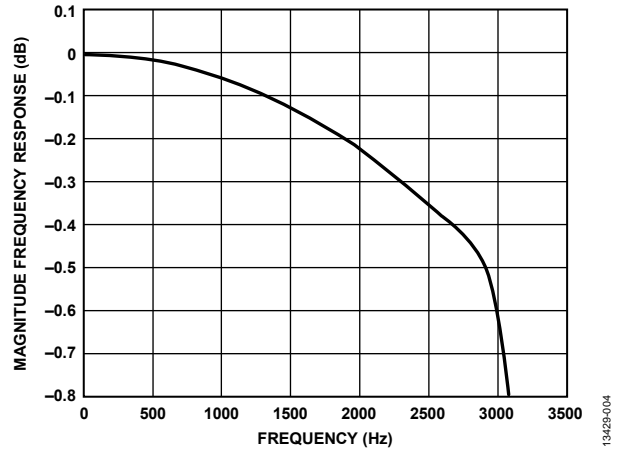


Figure 4. Flat-Band Response for ODR = 8 kHz and BW = 3.338 kHz

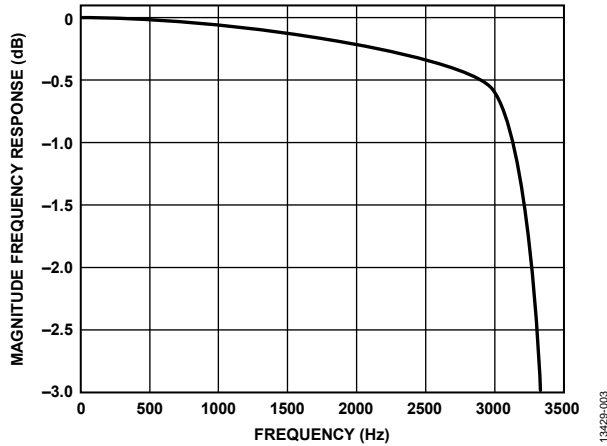


Figure 3. 3 dB Point Response for ODR = 8 kHz and BW = 3.338 kHz

Table 2. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-0.32	-0.87	-1.66	-2.67	-3.93	-5.44	-7.21	-9.26

Table 3. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 500 Hz to 900 Hz

	Frequency (Hz)								
	500	550	600	650	700	750	800	850	900
Magnitude (milli_dB)	-11.6	-14.22	-17.15	-20.40	-23.97	-27.87	-32.11	-36.69	-41.61

Table 4. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 950 Hz to 1350 Hz

	Frequency (Hz)								
	950	1000	1050	1100	1150	1200	1250	1300	1350
Magnitude (milli_dB)	-46.86	-52.45	-58.37	-64.6	-71.13	-77.95	-85.05	-92.41	-100

Table 5. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 1400 Hz to 2200 Hz

	Frequency (Hz)								
	1400	1500	1600	1700	1800	1900	2000	2100	2200
Magnitude (dB)	-0.108	-0.124	-0.141	-0.159	-0.177	-0.197	-0.218	-0.241	-0.265

Table 6. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 2300 Hz to 3100 Hz

	Frequency (Hz)								
	2300	2400	2500	2600	2700	2800	2900	3000	3100
Magnitude (dB)	-0.291	-0.318	-0.346	-0.374	-0.402	-0.434	-0.486	-0.6	-0.859

Table 7. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz; Frequency Range = 3200 Hz to 3500 Hz

	Frequency (Hz)				
	3200	3300	3338	3400	3500
Magnitude (dB)	-1.414	-2.452	-3.0	-4.09	-6.27

Table 8. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 8 kHz and BW = 3.338 kHz

	Frequency (Hz)								
	50	500	750	1000	1500	2000	2500	3000	3300
Phase Delay (μs)	225	226	227	229	234	241	254	277	321

ODR = 8 kHz and BW = 2.137 kHz

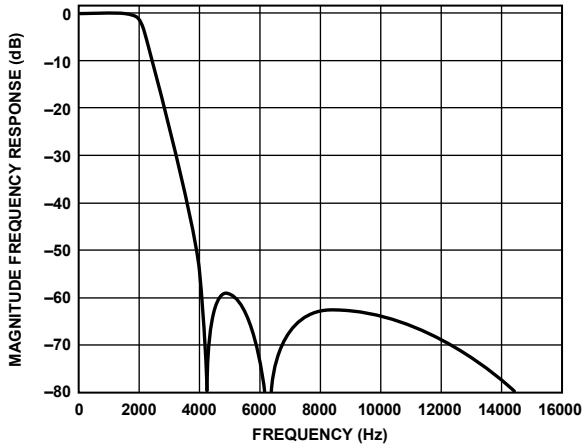


Figure 5. Full Frequency Response for ODR = 8 kHz and BW = 2.137 kHz

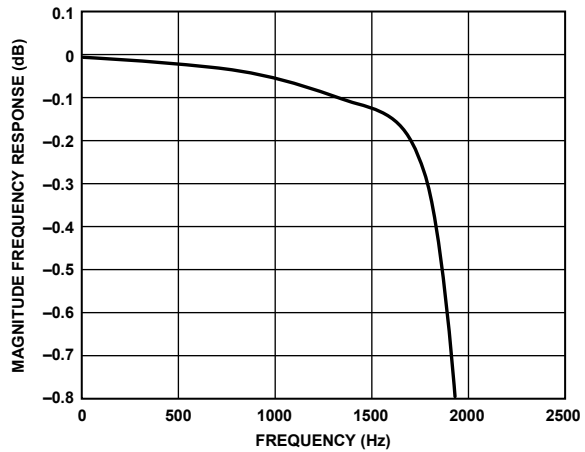


Figure 7. Flat-Band Response for ODR = 8 kHz and BW = 2.137 kHz

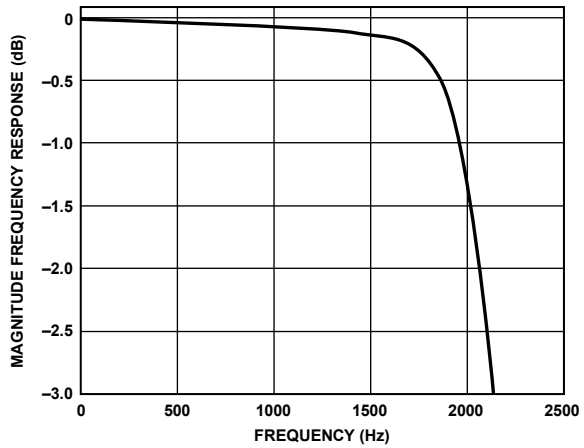


Figure 6. 3 dB Point Response for ODR = 8 kHz and BW = 2.137 kHz

Table 9. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 2.137 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-0.56	-1.5	-2.77	-4.34	-6.19	-8.25	-10.51	-12.91

Table 10. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 2.137 kHz; Frequency Range = 500 Hz to 900 Hz

	Frequency (Hz)								
	500	550	600	650	700	750	800	850	900
Magnitude (milli_dB)	-15.44	-18.08	-20.82	-23.68	-26.70	-29.90	-33.36	-37.13	-41.29

Table 11. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 2.137 kHz; Frequency Range = 950 Hz to 1400 Hz

	Frequency (Hz)								
	950	1000	1050	1100	1150	1200	1250	1300	1400
Magnitude (milli_dB)	-45.90	-51.01	-56.64	-62.8	-69.41	-76.40	-83.64	-90.96	-105

Table 12. SINC4 + LPF Gain Response at Various Frequencies for ODR = 8 kHz and BW = 2.137 kHz; Frequency Range = 1500 Hz to 2200 Hz

	Frequency (Hz)								
	1500	1600	1700	1800	1900	2000	2100	2137	2200
Magnitude (dB)	-0.119	-0.140	-0.188	-0.314	-0.621	-1.274	-2.243	-3.01	-4.167

Table 13. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 8 kHz and BW = 2.137 kHz

	Frequency (Hz)								
	50	500	750	1000	1500	1750	2000	2100	
Phase Delay (μs)	294	296	299	304	322	338	365	377	

ODR = 4 kHz and BW = 1.67 kHz

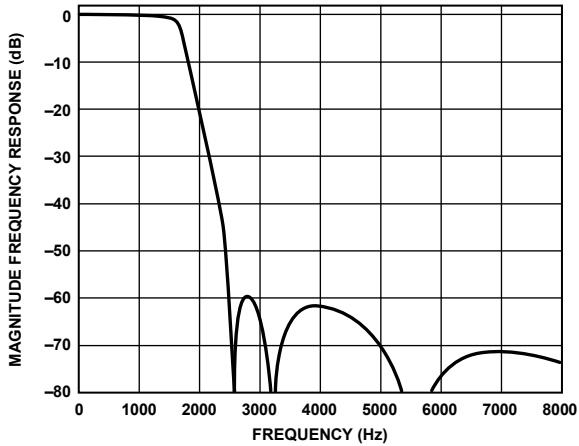


Figure 8. Full Frequency Response for ODR = 4 kHz and BW = 1.67 kHz

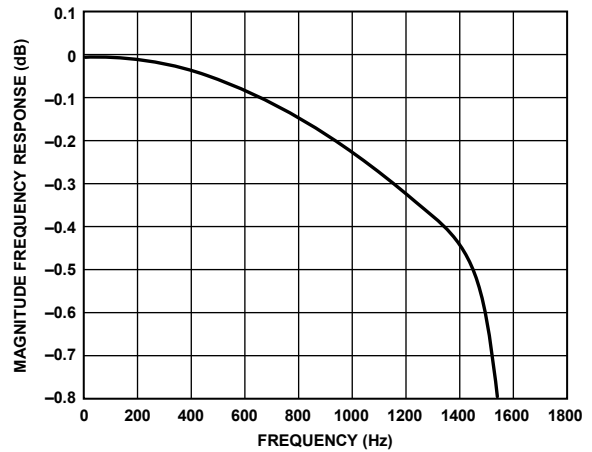


Figure 10. Flat-Band Response for ODR = 4 kHz and BW = 1.67 kHz

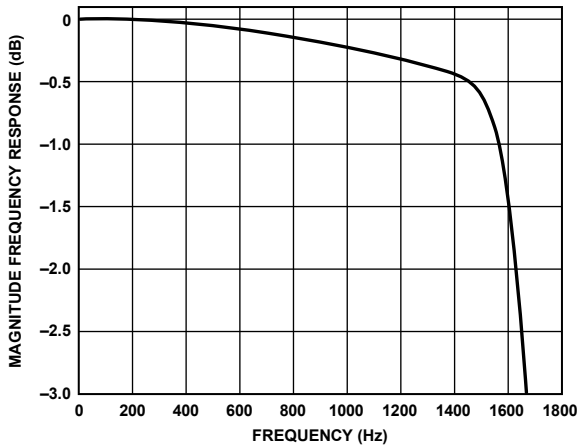


Figure 9. 3 dB Point Response for ODR = 4 kHz and BW = 1.67 kHz

Table 14. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.67 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-1.323	-3.589	-6.865	-11.234	-16.784	-23.596	-31.732	-41.222

Table 15. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.67 kHz; Frequency Range = 500 Hz to 900 Hz

	Frequency (Hz)								
	500	550	600	650	700	750	800	850	900
Magnitude (milli_dB)	-52.06	-64.199	-77.554	-92.011	-107.44	-123.73	-140.81	-158.66	-177.37

Table 16. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.67 kHz; Frequency Range = 950 Hz to 1350 Hz

	Frequency (Hz)								
	950	1000	1050	1100	1150	1200	1250	1300	1350
Magnitude (dB)	-0.197	-0.218	-0.240	-0.265	-0.291	-0.318	-0.346	-0.373	-0.401

Table 17. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.67 kHz; Frequency Range = 1400 Hz to 1900 Hz

	Frequency (Hz)								
	1400	1450	1500	1550	1600	1670	1700	1800	1900
Magnitude (dB)	-0.433	-0.486	-0.598	-0.856	-1.407	-3.01	-4.071	-8.807	-14.39

Table 18. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 4 kHz and BW = 1.67 kHz

	Frequency (Hz)							
	50	250	500	750	1000	1250	1500	1650
Phase Delay (μs)	450	452	458	467	483	508	555	608

ODR = 4 kHz and BW = 1.069 kHz

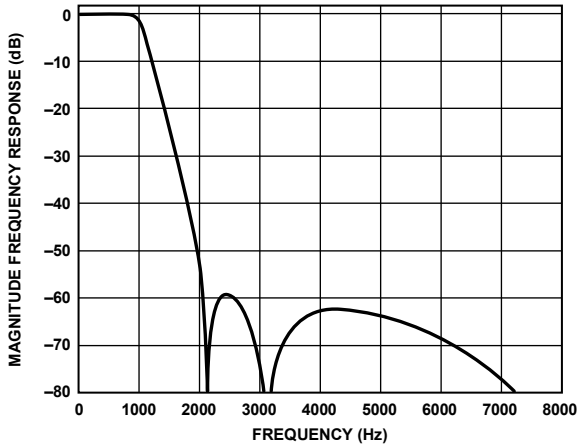


Figure 11. Full Frequency Response for ODR = 4 kHz and BW = 1.069 kHz

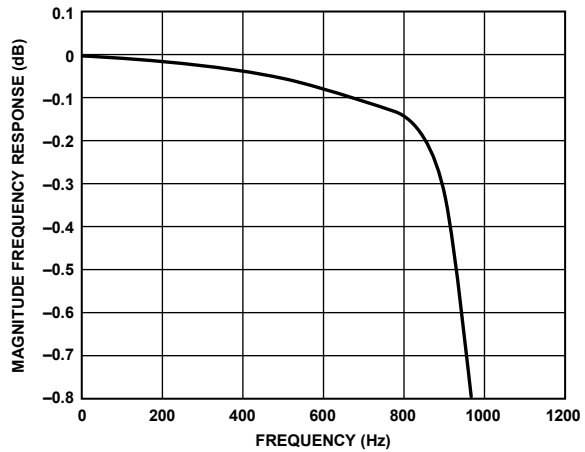


Figure 13. Flat-Band Response for ODR = 4 kHz and BW = 1.069 kHz

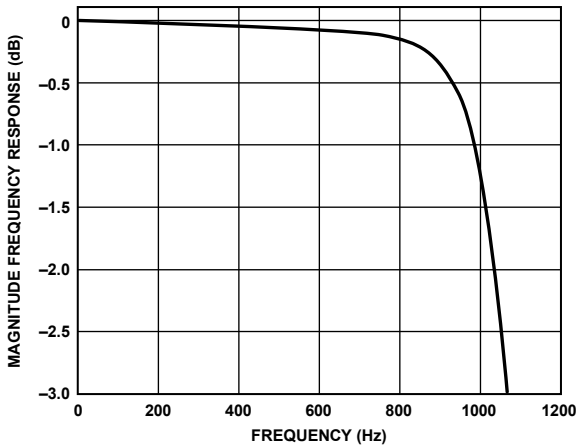


Figure 12. 3 dB Point Response for ODR = 4 kHz and BW = 1.069 kHz

Table 19. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.069 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-2.19	-5.60	-9.92	-14.85	-20.23	-26.10	-32.76	-40.68

Table 20. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.069 kHz; Frequency Range = 500 Hz to 900 Hz

	Frequency (Hz)								
	500	550	600	650	700	750	800	850	900
Magnitude (milli_dB)	-50.39	-62.16	-75.77	-90.33	-104.7	-119.2	-139.8	-186.9	-311.5

Table 21. SINC4 + LPF Gain Response at Various Frequencies for ODR = 4 kHz and BW = 1.069 kHz; Frequency Range = 950 Hz to 1300 Hz

	Frequency (Hz)								
	950	1000	1050	1069	1100	1150	1200	1250	1300
Magnitude (dB)	-0.617	-1.265	-2.423	-3.015	-4.147	-6.326	-8.776	-11.343	-13.936

Table 22. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 4 kHz and BW = 1.069 kHz

	Frequency (Hz)						
	50	250	500	750	1000	1250	
Phase Delay (µs)	588	593	609	643	730	795	

ODR = 2 kHz and BW = 0.836 kHz

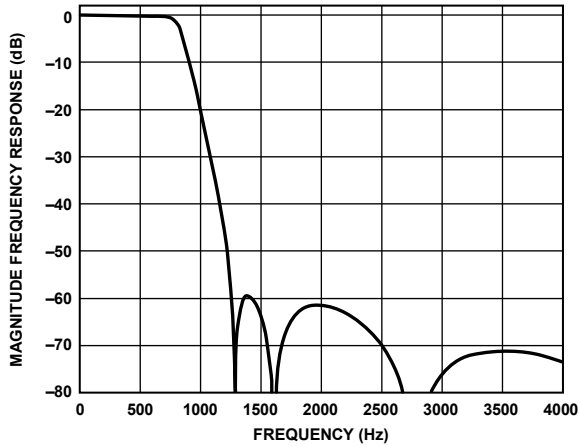


Figure 14. Full Frequency Response for ODR = 2 kHz and BW = 0.836 kHz

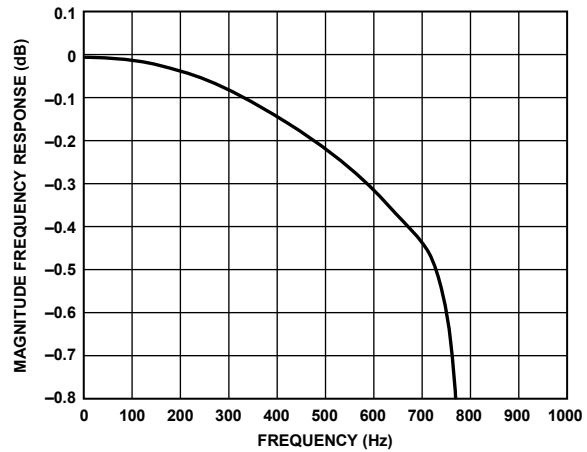


Figure 16. Flat-Band Response for ODR = 2 kHz and BW = 0.836 kHz

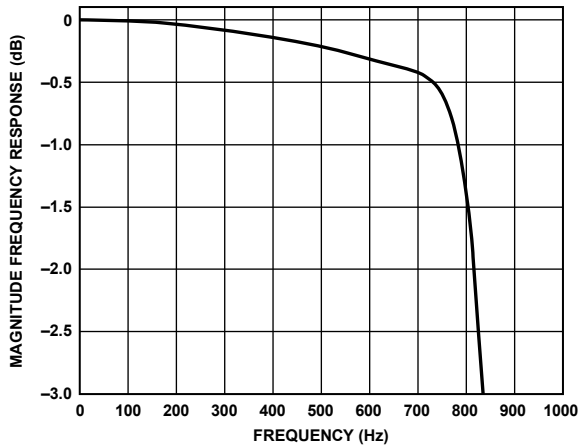


Figure 15. 3 dB Point Response for ODR = 2 kHz and BW = 0.836 kHz

Table 23. SINC4 + LPF Gain Response at Various Frequencies for ODR = 2 kHz and BW = 0.836 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-5.5	-15.37	-30.27	-50.55	-76	-106	-139	-176

Table 24. SINC4 + LPF Gain Response at Various Frequencies for ODR = 2 kHz and BW = 0.836 kHz; Frequency Range = 500 Hz to 1000 Hz

	Frequency (Hz)											
	500	550	600	650	700	750	800	836	850	900	950	1000
Magnitude (dB)	-0.216	-0.263	-0.316	-0.372	-0.431	-0.594	-1.39	-3.05	-4.03	-8.75	-14.33	-20.0

Table 25. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 2 kHz and BW = 0.836 kHz

	Frequency (Hz)							
	50	125	250	350	400	500	750	830
Phase Delay (μs)	901	904	915	930	939	965	1109	1223

ODR = 2 kHz and BW = 0.535 kHz

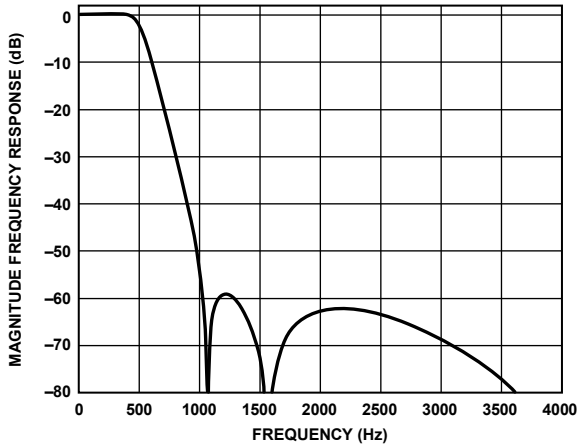


Figure 17. Full Frequency Response for ODR = 2 kHz and BW = 0.535 kHz

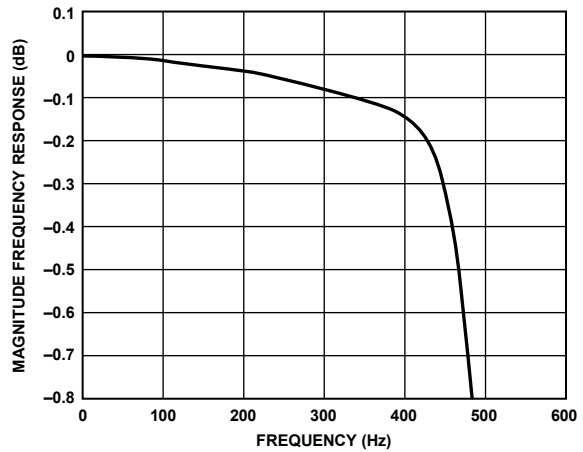


Figure 19. Flat-Band Response for ODR = 2 kHz and BW = 0.535 kHz

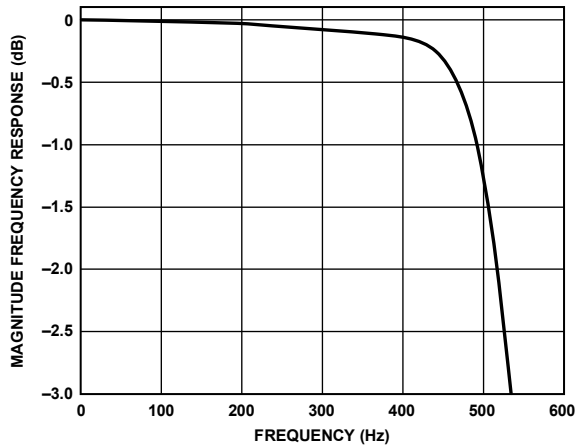


Figure 18. 3 dB Point Response for ODR = 2 kHz and BW = 0.535 kHz

Table 26. SINC4 + LPF Gain Response at Various Frequencies for ODR = 2 kHz and BW = 0.535 kHz; Frequency Range = 50 Hz to 450 Hz

	Frequency (Hz)								
	50	100	150	200	250	300	350	400	450
Magnitude (milli_dB)	0	-7.69	-17.99	-30.48	-48.05	-73.36	-102.34	-137.17	-305.62

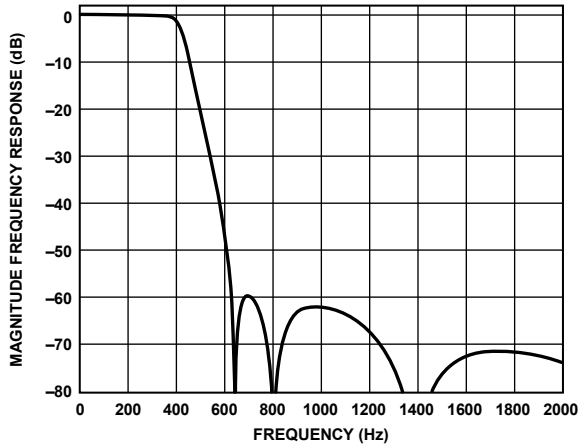
Table 27. SINC4 + LPF Gain Response at Various Frequencies for ODR = 2 kHz and BW = 0.535 kHz; Frequency Range = 500 Hz to 750 Hz

	Frequency (Hz)						
	500	535	550	600	650	700	750
Magnitude (dB)	-1.24	-3.01	-4.10	-8.72	-13.88	-19.01	-24.03

Table 28. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 2 kHz and BW = 0.535 kHz

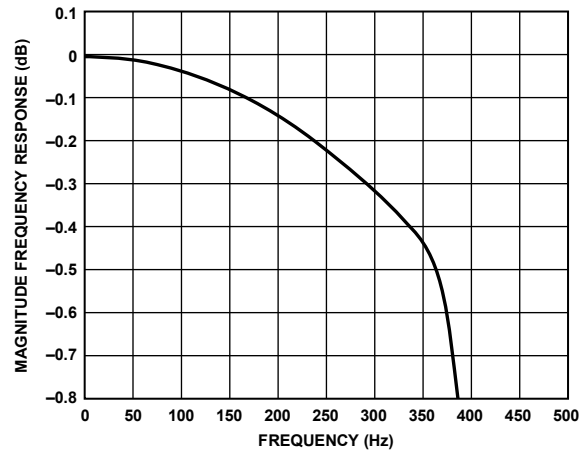
	Frequency (Hz)						
	50	125	250	350	400	500	535
Phase Delay (µs)	1177	1185	1217	1268	1309	1459	1525

ODR = 1 kHz and BW = 0.418 kHz



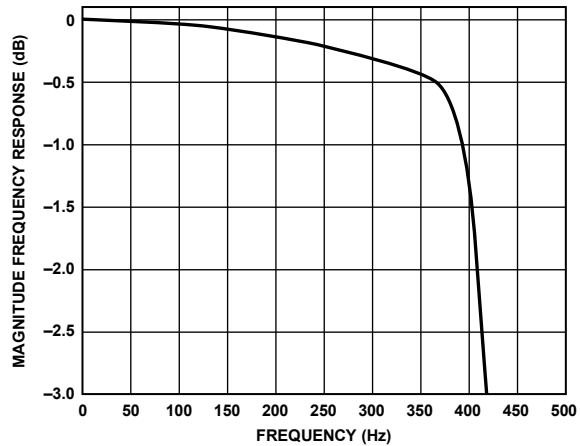
13429-020

Figure 20. Full Frequency Response for ODR = 1 kHz and BW = 0.418 kHz



13429-022

Figure 22. Flat-Band Response for ODR = 1 kHz and BW = 0.418 kHz



13429-021

Figure 21. 3 dB Point Response for ODR = 1 kHz and BW = 0.418 kHz

Table 29. SINC4 + LPF Gain Response at Various Frequencies for ODR = 1 kHz and BW = 0.418 kHz; Frequency Range = 50 Hz to 600 Hz

	Frequency (Hz)												
	50	100	150	200	250	300	350	400	418	450	500	550	600
Magnitude (dB)	0	-0.024	-0.070	-0.133	-0.210	-0.310	-0.424	-1.355	-2.98	-8.64	-19.95	-31.74	-45.78

Table 30. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 1 kHz and BW = 0.418 kHz

	Frequency (Hz)							
	50	100	150	200	250	300	350	400
Phase Delay (μs)	1806	1820	1843	1879	1930	2005	2122	2349

ODR = 1 kHz and BW = 0.268 kHz

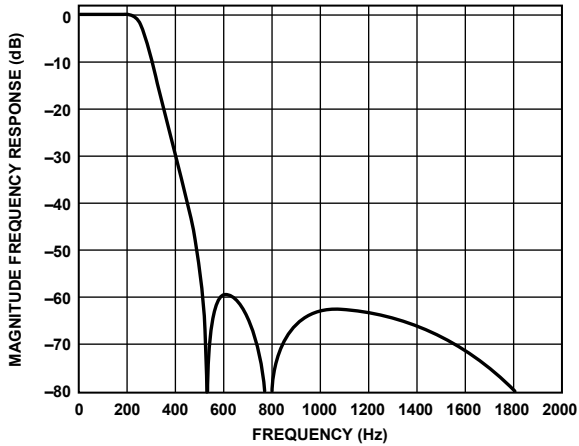


Figure 23. Full Frequency Response for ODR = 1 kHz and BW = 0.268 kHz

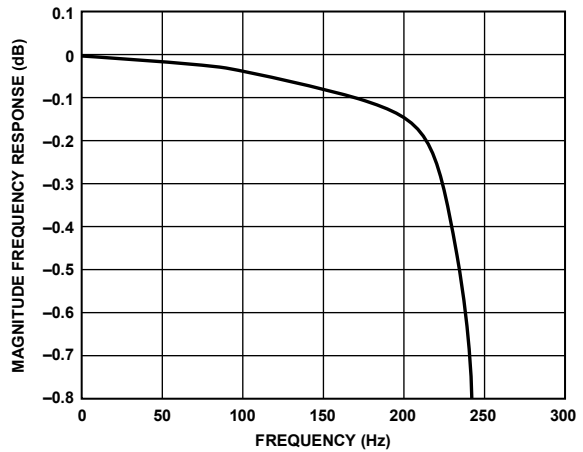


Figure 25. Flat-Band Response for ODR = 1 kHz and BW = 0.268 kHz

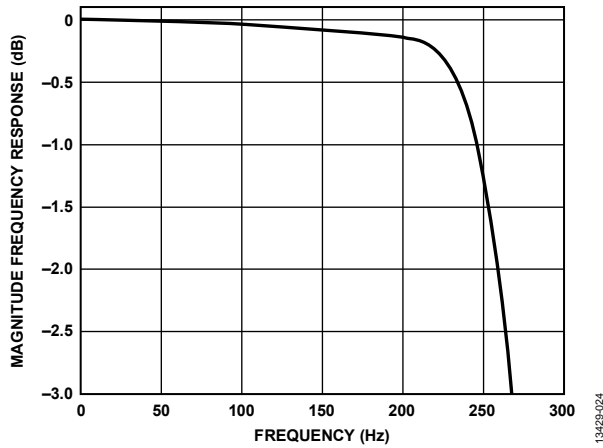


Figure 24. 3 dB Point Response for ODR = 1 kHz and BW = 0.268 kHz

Table 31. SINC4 + LPF Gain Response at Various Frequencies for ODR = 1 kHz and BW = 0.268 kHz; Frequency Range = 50 Hz to 400 Hz

	Frequency (Hz)								
	50	100	150	200	250	268	300	350	400
Magnitude (dB)	0	-0.022	-0.065	-0.128	-1.20	-3.0	-8.615	-18.9	-28.91

Table 32. SINC4 + LPF Phase Delay Response at Various Frequencies for ODR = 1 kHz and BW = 0.268 kHz

	Frequency (Hz)				
	50	100	150	200	250
Phase Delay (μs)	2363	2402	2477	2615	2913