Selecting PDM Microphone Clock Frequencies and Decimation Ratios

INTRODUCTION

A Pulse Density Modulation (PDM) microphone uses a Sigma-Delta modulator to oversample an acoustic signal at a high sampling rate. This digital PDM signal is output from the microphone as a 1-bit data word, where the density of ones and zeros in the data represents the amplitude of the audio signal. An audio codec or DSP cannot typically process this 1-bit PDM signal directly, so the signal needs to be decimated to the baseband audio sampling rate. Signals at this baseband sampling rate are what is processed, stored and played back in digital audio systems.

Selecting the proper PDM clock and baseband sampling frequencies is important for applications using PDM microphones. This application note describes the relationship between these two frequencies and can help a system designer to select the appropriate clocks for an application.

CLOCK RELATIONSHIPS

The data output from a PDM microphone is typically connected to an audio ADC, codec, or processor. For simplicity of discussion, this application note will assume that the PDM microphone is connected to a codec, as illustrated in Figure 1. Here, the codec supplies the clock to the microphone and the mic's output data is an input to this codec. The frequency of the codec's clock output (f_{PDM}) is typically between 512 kHz and 4.8 MHz.

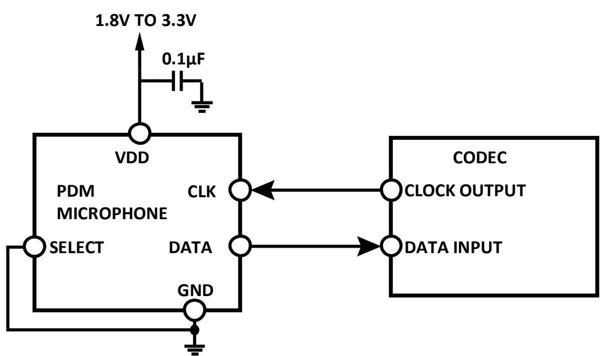

Figure 1. Mono PDM Microphone Connection to Codec

The codec's PDM data inputs are connected to a decimation filter block in the codec IC. This filter, usually implemented in hardware on the codec, is what reduces the high sampling rate used for the PDM data to the baseband audio sampling rate and converts the 1-bit PDM data stream to a multi-bit data word of usually at least 16 bits. The rest of the audio system can natively process this decimated signal. The Nyquist frequency, or half of the baseband sampling rate (f_s), defines the audio bandwidth that the decimated signal represents. This baseband sampling rate, at a frequency 2× the audio bandwidth, is typically 8 to 48 kHz, although certain applications may use higher frequencies. The decimation filter has a low-pass response with a steep roll-off at $f_s/2$ and significant attenuation at higher frequencies.

The codec may be able to provide a range of clock frequencies to the PDM microphone and the decimation filter usually has a range of different ratios to which it can be set. The decimation ratio defines the relationship of a PDM microphone's clock frequency (f_{PDM}) to the baseband sampling rate (f_s) by this simple equation:

$$f_s = f_{PDM} / \text{decimation ratio}$$

This decimation ratio is represented as a multiplier, such as "64×." For a given decimation ratio, a higher PDM clock frequency will enable the system to capture a wider audio bandwidth and may enable lower-noise performance of the PDM microphone in the system.

SELECTING CLOCK FREQUENCIES FOR AN APPLICATION

The decimation ratio is usually set between 25 and 64×. A higher decimation ratio (larger numeric multiplier) will filter more of the out of band noise generated by the Sigma-Delta modulator, but will require high PDM clock frequencies. Higher clock frequencies in a design may result in higher power consumption by both the microphone and codec. A decimation filter set to a lower ratio will not filter as much out of band noise but may enable lower power consumption. If a system design has flexibility in both the PDM clock frequency and decimation ratio, then a system designer can trade off those two settings against each other to optimize for either power or audio performance. Figure 2 shows the measured current consumption of the ICS-41350 PDM microphone across different PDM clock frequencies. This specific microphone features two different power modes, so at lower clock frequencies, the current draw is significantly lower when compared to operation at higher clock frequencies in its Standard Mode. With this microphone, there is a slight (1 dB) reduction in SNR in Low Power Mode that a designer can balance against the lower power consumption in this mode.

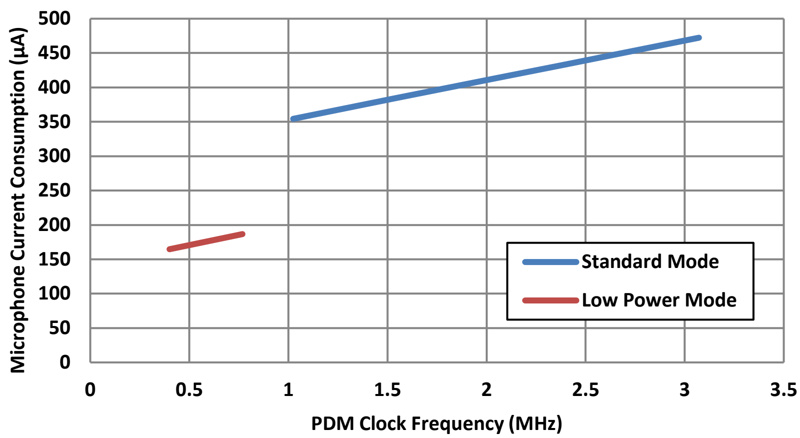

Figure 2. ICS-41350 Current Consumption at Different PDM Clock Frequencies (f_{PDM}), V_{DD} = 1.8 V

Table 1 shows examples of common PDM clocks and decimation ratios along with the resulting baseband sampling rate, audio bandwidth, and appropriate applications. Notice that different combinations of clock frequency and decimation ratios may result in the same baseband sampling rate.

TABLE 1. COMMON CLOCK AND DECIMATION RATIO SETTINGS

PDM Clock Frequency (f_{PDM})	Decimation Ratio	Baseband Sampling Rate (f_s)	Audio Signal Bandwidth ($f_s/2$)	Applications
4.8 MHz	25×	192 kHz	96 kHz	Ultrasound
4.8 MHz	50×	96 kHz	48 kHz	
3.072 MHz	64×	48 kHz	24 kHz	Full-bandwidth audio
2.4 MHz	50×	48 kHz	24 kHz	
1.536 MHz	48×	32 kHz	16 kHz	Wide-bandwidth audio
1.024 MHz	64×	16 kHz	8 kHz	High-quality voice
768 kHz	48×	16 kHz	8 kHz	
512 kHz	32×	16 kHz	8 kHz	
512 kHz	64×	8 kHz	4 kHz	Standard voice

REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
4/3/2017	1.0	Initial Release

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